TRANSACTIONS

OF

THE AMERICAN SOCIETY

OF

HEATING AND VENTILATING ENGINEERS

VOL. VI.

SIXTH ANNUAL MEETING

NEW YORK, JANUARY 23-25

1900

PUBLISHED BY THE SOCIETY
AT THE OFFICE OF THE SECRETARY
NEW YORK CITY

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LXIX.

THE AMERICAN SOCIETY

OF

HEATING AND VENTILATING ENGINEERS.

SIXTH ANNUAL MEETING.

New York City, January 23, 24, 25, 1900.

PROCEEDINGS.

First Session.

The meeting was called to order by President Henry Adams, in the rooms of the American Society of Mechanical Engineers, No. 12 West 31st Street, New York City, at 2.30 P.M., on Tuesday, January 23, 1900.

Secretary W. M. Mackay called the roll.

The President having announced the presence of a quorum, on motion, the reading of the minutes was dispensed with.

The President then read the following address:

ADDRESS OF THE PRESIDENT.

It gives me great pleasure, gentlemen, to extend to you a most hearty welcome to this, our sixth annual convention, and I trust that this meeting will be both instructive and pleasant to every individual member and visitor.

The past year has been a memorable one and the prosperity of the country, no doubt, has been felt by our members. It is especially gratifying to see the attendance at this meeting, which is evidence that the object and aim of our society have not lagged during the past year.

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While no special effort has been made to enroll new members, the membership has been slightly increased, notwithstanding the fact that in accordance with the Constitution and By-Laws, a number were dropped for non-payment of dues.

Since the formation of this society, the heating and ventilating engineers of other countries have formed societies similar to our own. This demonstrates the constantly increasing importance of our branch of engineering, and the wisdom of combining for the purpose of advancing the arts and sciences in connection with it.

The reports of your officers, of the Chairman of the Board of Managers, the Chairman of the Council, and the Special Committees, will give you the details of work done by the society during the past year.

The progress made since our formation has been slow but sure, and to-day the necessity for proper warming and ventilating of all classes of buildings is being more generally recognized than ever before. Much more, however, remains to be done, and the continued earnest efforts of each individual member will be required to finally attain the high standards and ideals of our society. This is especially the case in connection with compulsory legislation; and in this respect I would request each member to make an effort in his own locality towards obtaining suitable legislation, in which efforts he will have the assistance of the committee having this in charge.

While the formulation of standards, and especially of tests, in connection with our branch of engineering is exceedingly difficult, I believe that the adoption of rules and regulations governing tests of heating and ventilating apparatus, and the fixing of standards will advance the interests of our society materially; for which reason I hope that the committees will soon be able to make definite reports.

The Transactions of our society to-day form a most valuable part of the available heating and ventilating literature which is printed in the English language. The data contained therein are of interest to both the practical and theoretical members of our society and are sought after by outsiders. Yet I do not consider it amiss to state that the talent enrolled on our list can do much more; and hence I appeal to you to sacrifice some of your valuable time in the interest of the society by writing

papers or briefly giving your experiences, as has been so nobly done by several members in the past. A number of our members are excellently fitted to scientifically develop formulas from the data of actual tests and experiments. Papers of this nature may seem too technical to some of us, but are, nevertheless, of great value, and the deductions therefrom of assistance to the manufacturer of heating and ventilating appliances—as well as to the designing engineer.

On the other hand, some of our practical members should come forward with more papers, giving their experience with engineering problems, which will always be the most valuable information and data for the investigator. By this method the members will be mutually benefited, and the branch of the engineering profession represented by our society constantly advanced.

In this connection I also express the hope that the society will soon be able to begin publishing a small monthly bulletin for the benefit of our members, as has been suggested and recommended by one of our former presidents, Mr. Jellett.

Before closing my remarks, I cannot refrain from mentioning a subject which so far has received little attention from the society, although of great importance; namely, the proper supervision and operation of heating and ventilating apparatus, especially in larger buildings. During my experience I have had frequent opportunity to examine work which was reported unsatisfactory, but upon inspection was found well designed and executed, being inoperative solely through incompetent attendants.

I have found this especially the case in schools and other public buildings, where the men in charge were entirely ignorant of the functions of any appliances under their care. To remedy such conditions, I consider, should also be an aim of the society.

The Secretary presented his report, as follows:

REPORT OF THE SECRETARY.

New York, Jan. 23, 1900.

Gentlemen: At the last annual meeting the society had 106 members, one honorary member, eight associates, and four juniors; a total of 119 members of all grades. During the past

year one member and one associate have resigned. One of our members, Mr. J. W. Gifford, of Attleboro, Mass., died on July 26, 1899. Four members, one associate, and one junior have been dropped from the rolls for non-payment of dues. One associate has been advanced to full membership. Nine members and two associates have been elected to membership and have qualified, their names being announced at the summer meeting. The membership of the society at present is 110 members, one honorary member, seven associates, and three juniors, a total of 121 members of all grades; a net gain of two over last year. In addition to this the Council has approved one application for membership, one for associate, one for junior, and one associate for full membership. These applications, together with such others as may be received and are approved, will be balloted for by the members after the annual meeting.

The funds of the society are not in such a condition as to best promote its welfare, but this can be remedied by the members, by a prompt payment of their annual dues, which will become due at this meeting. The expenses of the year have been fairly heavy, some of them being chargeable to the previous year, and others, while incurred during the year—particularly the printing and stereotyping of the constitution, articles of incorporation, and directory of the society—will reduce the expense of future years.

It was found that the officers could not give sufficient time to the work of properly editing the annual proceedings, and a competent editor was employed. The amount paid during the past year for editing and printing the 1898 proceedings was $556.54. A new constitution was presented at the last annual meeting, and, after being voted on by the entire membership by letter ballot, was unanimously adopted and ordered printed; the cost of this work being $73.61.

The expenses of the delegation to the Legislature at Albany, N. Y., in connection with the Compulsory Ventilation bill was $34.82. The balance in the hands of the treasurer at the close of the last annual meeting was $305.30, including $5 belonging to the Hart fund.

There was received during the past year from all sources, $1,408.09, making a total of $1,713.39. The total expenditure

was $1,680.38, leaving a balance in the hands of the treasurer of $33.01, as will be shown in his report.

The secretary's expenses for the year, including stenographer, clerk hire, postage, rent of P. O. Box, expressage, etc., amounted to $300.12. There is a balance due the printer for advance copies of papers for summer meeting and balance on annual proceedings of $315.83, and a balance due the secretary of $58, making a total indebtedness of $373.83, to meet which we have still owing by members for dues, $215. This, with the balance in the general fund, makes a total of $227.44, or a deficit of $146.39.

The six members dropped from the rolls during the year owed the society $195, so that had all members met their obligations to the society, there would have been a balance on hand after paying all indebtedness.

In addition to the amount already mentioned, there will become due at the close of this meeting, for dues, about $1,200, or a total of about $1,400, with which to meet past indebtedness and the coming year's expenses, and I would urge on the members the necessity of prompt payment so that the affairs of the society and its influence for the good of our profession will not be curtailed in any way by lack of funds.

The annual proceedings for 1899 are in the hands of the printer, with the exception of some corrections, which have just been received and which have delayed the publication of the volume. It is now being completed and will be forwarded to the members possibly inside of the next sixty days.

The society held a semi-annual meeting at Saratoga, N. Y., on July 21 and 22, 1899, and while it was not as well attended in point of numbers as was expected and desired, those present evinced a marked interest in the entire programme and expressed themselves as amply repaid for their journey.

Ten members have obtained the society's pin badge from the secretary during the past year. These badges can be procured through the secretary at any time.

The annual proceedings of the society are sent free to twenty-nine of the leading colleges, engineering and architectural societies, the list being increased from year to year.

The papers to be presented at this meeting were late in being received. The majority of them only reached the secretary dur-

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ing the past ten days, and as there were thirty-four cuts to be prepared and the papers edited and corrected, it has delayed the publication of them so that they could not be forwarded to the members in time to have them prepare a written discussion on them. In fact all of them have not been received from the printer yet, but are promised for Wednesday.

I would urge on the members the necessity of sending in papers for future meetings earlier. By doing so they will assist the secretary in his work and insure making a greater success of the meetings.

WM. M. MACKAY, Secretary.

On motion, the report of the secretary was accepted and ordered to be put in the minutes.

The treasurer's report was then presented, as follows:

REPORT OF THE TREASURER.

New York, Jan. 23, 1900.

Balance on hand, Jan. 24, 1899.....	$305.30	
Cash received since that date—Initiation fees, dues, etc.....	1,408.09	$1,713.39
Disbursements for the society.....		1,680.38
Balance in Washington Trust Company.		$33.01

The balance in the Washington Trust Company, includes the

Balance of the Hart fund.....	$5.00
Balance of annual dinner fund.....	15.57
General fund.....	12.44
	$33.01

Respectfully submitted,
JUDSON A. GOODRICH, Treasurer.

The President: We will pass to the next report, which is the report of the Chairman of the Board of Managers.

Mr. Jellett then read the following report:

REPORT OF THE BOARD OF MANAGERS.

The Board of Managers held twelve regular meetings during the year just closed, in addition to a number of meetings between the chairman of the board and the secretary and other officers of the society on matters affecting the society's welfare.

At the first meeting of the board held after the annual meeting of 1899, Mr. Stewart A. Jellett was elected chairman, and at the same meeting Mr. Wm. Kent was elected a member of the board to fill the vacancy created by the resignation of Mr. Henry C. Meyer, Jr., who found himself so situated as to be unable to serve. At the second meeting of the board, the chairman was elected a committee to prepare and submit to members for vote the proposed new Constitution and By-laws, in accordance with instructions given at the last annual meeting. This has been done, and the membership approving, copies have been printed and forwarded to all members some months back.

Under a resolution passed at the last annual meeting, a semi-annual meeting was held at Saratoga Springs, N. Y., on July 21 and 22, 1899. At this meeting papers of great interest were read and discussed, but we regret to state the attendance of our members fell far short of expectations, and we would ask your consideration at this meeting as to whether it is wise to hold semi-annual meetings of our society until our membership and income have both materially increased, or whether it is not better to concentrate our efforts on the annual meetings and make them a greater success.

The reports of the Council and of the secretary and the treasurer will give you full information as to membership, receipts and expenditures, and other matters of interest. Your board, however, desire at this time to call your special attention to the finances and the financing of our society, both for your information and for that of our successors, the incoming Board of Governors. We feel that the past year has been the crucial one (from a financial standpoint) for our society, and having weathered it more or less successfully, we should be encouraged to enter upon a broader field of usefulness. To summarize the situation briefly: there was in the hands of the treasurer on Jan. 26, 1899, the sum of $305.30, and there were outstanding dues amounting to $260.28. There has been received since that date

from all sources, $1,408.09, making the total sum available for the year, $1,713.39. Not a very large sum for the conduct of the business of our society for one year. But from the back dues we have been compelled to cross off a total sum of $215, representing the amount owing the society by members who were dropped from the rolls under Sections 2 and 3, Article VIII. of our By-Laws, and we regret to say there is at this date the sum of $215 due the society from members, all of which should have been received during February, 1899. With the general business prosperity prevailing in all lines during the past year, we cannot but feel that this delinquency on the part of some of our members is to be regretted. The receipt of this money when due would have greatly assisted your board in the conduct of the society's affairs. The expenses of the society have been kept within close limits. The entire expenses of the secretary for the year amounts to $300.12. This includes postage, rent of P. O. box, services of stenographer, etc. Certainly an average of $25 per month for all such services is a small amount. What might be classed as special expenses for the year was the cost of printing the new Constitution and list of members, amounting to $73.61 and the expenses of a committee to Albany to assist, if possible, in the passage of a bill to make it compulsory to ventilate schoolhouses, etc.; this sum was $34.82, a total of unusual expenses of $108.43. The cost of getting out cuts for the summer meeting papers was $145.25, for printing the papers for the same meeting, $159.29, and for stenographer's services at meeting, $73.40, making the total expense of holding the meeting $377.94. We close the year, therefore, owing $373.83, and with an asset of $215 due from members and with $33.01 in the hands of the treasurer. It is therefore quite evident that our society is not in a position to afford a summer semi-annual meeting, although the results in papers and discussions have been very satisfactory.

In conclusion, let us remember that all societies similar to ours have passed through practically the same experience as we have. Upon organization and for a short time thereafter a large number of men apply and are admitted who have no very full conception of the work it is intended the society shall perform. Such members having no real interest in the society, later on ignore their obligations in the matter of dues, etc., and after

being carried on the roll until patience ceases to be a virtue are dropped. This weeding-out process, which is to the interest of the organization, has been going on in our society and is now practically completed, and from now on the society should be free from drawbacks of this nature. The membership to-day is composed of men having at heart the interests the society was organized to promote. The rules governing admissions are stringent enough to keep out those who are ineligible for membership and broad enough to admit all who are qualified. With this meeting the old order of two separate boards—the Council and the Board of Managers—passes out of existence, and the new Board of Governors, with enlarged powers and responsibilities, takes their place.

May we indulge the hope that the members will give them the support they should and must have if the society is to fully meet the expectation of its founders?

Respectfully submitted,

STEWART A. JELLETT, Chairman.

On motion, the report of the Board of Managers was accepted.

The report of the Council was then read by Mr. Gormly, in the absence of the chairman, Prof. R. C. Carpenter.

REPORT OF THE COUNCIL.

The Council has held seven meetings since the last annual meeting, acting on all applications for membership received, most of which were approved.

Nine new members and two associates were added to our rolls and one associate was advanced to full membership. Three additional applications were also approved and will be presented to the membership later, with one associate approved for full membership and such other applications as may be received and approved at, or immediately after, this meeting.

The Council also passed on the various papers presented by the members for the summer meeting, at Saratoga, N. Y., and for this meeting, all of which were carefully edited and advance copies ordered printed for distribution to the members. The late date at which the papers were received and the necessity for

cuts in some of them, prevented their being printed and reaching the members as early as the Council would have liked, in order that the members might have ample time to read and prepare a discussion on them, before the meeting, and your Council would suggest that papers for presentation at any meeting of the society, should be in the hands of the secretary at least thirty days in advance of the meeting, so as to give ample time for editing and the preparation of cuts, so as to get the papers out in the best possible shape (instead of in a hurried and incomplete manner) and in the hands of the members as much in advance of the meeting as possible, so that the full value of each paper may be brought out and the society benefited by its presentation and discussion.

The Council would also suggest that the membership secure the application of such persons in their vicinity as are eligible for membership, as there are a number who are fully qualified who are not members of our society.

R. C. CARPENTER, Chairman.

On motion, the report of the Council was accepted and ordered spread upon the minutes.

The President: The next order of business is the reports of special committees, of which there are several, and the first committee is the Committee on Compulsory Legislation, of which Mr. Wiltsie F. Wolfe is chairman.

Secretary Mackay: No report has been received from Mr. Wolfe.

The President: Mr. Jellett, has anything been done in connection with the question of compulsory legislation?

Mr. Jellett: I can give a verbal report. The committee visited Albany in the interests of the bill as presented there, and the bill has been advanced somewhat on the calendar. The efforts of the committee, I think, have helped materially in getting it there. But from the information we have been able to obtain from different sections it is going to take time to get any such bill passed. The opposition comes principally from country members, who, as one put it to me at Harrisburg, can get all the ventilation they want by going out for a drive; and as rural members constitute the majority of the Legislature, it has to be a slow development. It is a matter of education. I took the

matter up at Harrisburg and the State boards of health of Pennsylvania agreed to back a bill of the kind, believing it to be necessary. It was on the calendar. I was told frankly that no power on earth could procure its passage at that session, but if it was on the calendar its chances of passing at the next session were materially increased, so we had it put on the calendar. The local committee of the State boards of health had it in charge, and, as they are in touch with all questions connected with public health at Harrisburg, when the time comes for it they expect to put the bill forward.

In Philadelphia the Board of Education has appointed a new committee on hygiene to look after the sanitary inspection of schools, but that is local and not affected by the State law in any way. I saw yesterday that they had held a meeting and decided to go into questions of drainage and ventilation more thoroughly than had been done in the past, and that new men had been put on the committee who had ideas in this direction. Mr. Wolfe has been more in touch in the matter with the members in different parts of the country, and I think when he comes that he will be able to give us very much more complete information. But as one of the committee I would report that we have made material progress during the past year.

The President: There is no doubt, gentlemen, that it is uphill work in obtaining legislation in the different States; but I trust that all the members will use their best efforts in this direction. I personally have taken steps to introduce a bill in the Maryland Legislature, and I have great hopes to pass it at this session. What the result will be I cannot tell, but the field seems to be ripe for it over there and I will push the matter as much as I can.

Secretary Mackay: I would like to state, while not a member of the committee, that the New Jersey representative of the committee stated to me verbally last week that he had succeeded in inducing Senator Mungle, of Essex County, who is very successful with bills that he introduces into the Legislature of New Jersey, to take the bill, which is virtually the bill presented at Albany last year, the only change made in it being a change really for the better. The bill at Albany, in order to overcome the opposition of some of the country members, was made to apply only to cities of ten thousand and larger. In New Jersey

they are to make it—as it was originally intended for New York State—five thousand and larger, and I believe, as it has been introduced the first week of the Legislature, that there is every possibility of New Jersey being on record as showing the first effort of our society in securing legislation. I hope so.

The President: Has any other member anything to state in regard to legislation?

We will pass to the next order of business, the report of the Committee on Standards. Professor Kinealy is chairman.

Prof. J. H. Kinealy: Mr. President, I have no written report, for the reason that the members of this committee were unable to get together before this meeting. I desire to say, however, that the committee have been working. We have been trying to devise a standard method of testing plants in place; that is, if a plant be put in during the summer months under a guarantee to keep the building at 70 degrees during zero weather, to find what method should be adopted for testing that plant during the warm weather of the fall. We have each of us given the matter consideration. We have had some correspondence back and forth. We have made some progress, but not much. I think that we have learned something not to do—perhaps more things that we ought not to do rather than things that we ought to do. We find it a difficult subject, a large subject, and we have been unable to come to any conclusion. I am not sure but that the matter should be taken up by a joint committee of the Committee on Standards and the Committee on Tests. It involves the whole subject of tests, of measuring temperature, of measuring returns, of measuring everything involved in the working of a heating plant, and in order that the committee might get some light upon this subject, I have had introduced as one of the topics of discussion the question: "What ought to be the maximum allowable error of any one test of a series of tests?" A full, frank, and open discussion on that subject will prove of value to the next Committee on Standards. I feel that the committee ought, perhaps, to have done more, but we have done our best, and let the next committee continue the work.

The President: Gentlemen, I heartily appreciate the efforts of the committee, and no doubt you do, and I hope that the Committee on Standards and Tests will continue, because it is very difficult to change committees of that nature who have

started that class of work, and because it is one of the most important things we have to accomplish—to get standard regulations and rules for testing, and no doubt, just as I have stated in my report, it will advance the interests of our society greatly. I thank Professor Kinealy very much.

The next report is the report of the Committee on Tests.

The secretary read the report of the Committee on Tests, as follows:

REPORT OF THE COMMITTEE ON TESTS.

Gentlemen: As no funds have been provided for the purpose of conducting tests, your committee has not been placed in a position to undertake investigations of heating or ventilating apparatus or systems, and further, as no work of this kind has been referred to us by the society or other interested persons during the past year, we are unable to embody in this report matters of interest to the society, as we earnestly wish we could.

We believe that the existence of this committee is not as widely known as it should be, and if architects and others interested in heating and ventilation knew of it, some of their disputed questions, meriting the notice of this society, might be submitted for final settlement, and as such work often is well worth the cost of investigation to the interested parties, the necessary attending expenses might be defrayed by them.

Your committee does not wish to be understood that tests would be undertaken for the purpose of helping manufacturers advertise their wares or systems, nor does it include the settlement of well-known troubles in various heating and ventilating systems, but it refers more to the investigation of such questions as would furnish the society with information of value and interest.

ALBERT A. CARY,
Chairman of Committee on Tests.

The President: The suggestion has been made by the chairman of the Board of Managers to dispense with our summer meeting. I think that the ground is well taken, and the money which is spent for the summer meeting may well be given to those two committees for making tests and establishing stand-

ards, and I want to give that to you to think over under the head of new business. I would like to hear an expression from the members on those subjects. What is your pleasure with respect to this report?

Mr. Jellett: I move that it be accepted, Mr. President.

The motion was seconded and carried.

The President: Gentlemen, the closing of the ballot for the election of officers will take place at half-past three. I appoint as tellers to count the ballots, Mr. Barron, Mr. Carpenter, and Mr. Cryer, who will report the result of counting the ballots at the evening session. The next order is new business.

Mr. Jellett: Mr. President, I think that the matters touched on in the various reports could be properly discussed now, because the first day's session is usually given up to business matters of the society; many of our members will not arrive until to-night or to-morrow morning, and they are especially interested in the papers, but are not so interested in the business; so that any questions affecting the business management of the society would better be discussed this afternoon than allowed to interfere with the programme later on when the papers and subjects will be discussed.

Now the question of the advisability of holding a summer meeting is a question that is open for discussion, and the question touched on in the president's address as to the advisability, when we can afford it, of publishing a monthly bulletin of information affecting heating and ventilation. All such matters as that, I think, would properly come up now and ought to bring out a good deal of discussion, because there are thirty or thirty-five members here.

Mr. Barron: I move that the Board of Governors be requested to hold a summer meeting and to invite to the meeting all the heating trade, and have a joint meeting of all those who are interested in the arts that we represent.

Mr. Jellett: For the sake of discussion, although I do not agree with Mr. Barron, I will second that motion.

Mr. Barron: My object is merely to have a discussion of the matter so that the Board of Governors could have the views of the society when they were considering that matter.

Mr. Jellett: Mr. President, I would like to have four meetings a year, if we could get the papers and could afford it. But

the experience of trying to make one dollar do a dollar and a half's worth of work last year has taught me that it is better to content ourselves with doing a dollar's worth of work first. The annual meeting can be made a good deal more of a success than it has been, I think. We ought to have more papers; we ought to have the papers earlier, and the information affecting the various topics should be looked up earlier. It is a very difficult thing to get what I call a satisfactory summer meeting. You can hardly pick out any time in July and August that will suit a large percentage of our members. At the meeting last summer we had papers and they were good ones, but they did not bring out the discussion they ought to because there were not enough men to discuss them. If those papers had been added to the annual meeting, when a much larger proportion of our membership was present, the papers would have had more value, because the discussion frequently brings out information that was not contained in the paper, or puts it in a different light, and if the papers of the summer meeting were added to the papers of the January meeting, I think that the January meeting would become such a meeting that our members could not afford to stay away from it. On the other hand, take the question of finance, with 121 members, with the fixed expenses that we are under, it is pretty hard work to pull through and do it in a creditable shape. It is not desirable to simply add to our membership. It is better to go slow and build a solid foundation of men who take an interest in the matter and who will be useful to the society. I am opposed to having a summer meeting until we are in a condition to have that summer meeting right.

The question of inviting the general heating trade throughout the country, I do not think will work, for the reason that the Master Steam Fitters' Association touches on trade questions, and takes in the trade generally throughout the country. They hold their annual meeting in June, and you cannot get them to come to another one in July. We tried the experiment here in New York of a summer meeting at the same time that the Steam Fitters held their convention; it was an evening meeting and was fairly successful. But you cannot get those men to come to our meeting and neglect their own, and if we have our meeting the day after theirs, there are not very many who will stay

over who live out of town, so we are limited to the men at home. I believe that our society should stand on its own feet, and if it cannot have a good meeting, not to have one at all.

Mr. Andrew Harvey: I agree fully with Mr. Jellett's idea in that particular case, because we have tried it now for three years. I know that I have only had the opportunity of attending one meeting, which was the year before last. I am satisfied that if we have one good meeting a year that more will be accomplished that way than to have two or three, at least with the present number of members.

Mr. Barron: I fully agree with Mr. Jellett. I have no positive views in the matter at all, but it is a matter that ought to be discussed, because it bears on the increase of membership and it bears on the financial question. But I certainly am no advocate of summer meetings. I simply made that motion so as to get the sense of this meeting, so that the Board of Governors would have the views of the membership.

Mr. Switzer: I move as an amendment to Mr. Barron's motion, that the semi-annual meeting be dispensed with, and that the annual meeting be made the one meeting of the society. I offer that as an amendment to Mr. Barron's motion.

Mr. Stangland: I second that motion, Mr. President.

Mr. Barron: If it is according to Cushing, Mr. President, I will accept the amendment.

The motion, as amended, was carried.

Mr. Switzer: In regard to the financial reports of the society it would seem that it would be only right and proper, by reason of the fact that we are to have a new Board of Governors to take charge of the affairs of the society for the ensuing year, that some arrangement should be made whereby the society could start in with a clean balance. A small indebtedness is reported. Some of the members seem to think that will be wiped out in the natural course of events and that things will shape themselves in such a way that ample funds will be provided. But I think that a clean balance sheet and a surplus, rather than a deficit, would be an advantage to the new Board of Governors and Managers for the year to come, and could not that be provided for now, say, by an assessment? I would like to hear an expression on that.

The President: What are the views of the gentlemen present

on this matter? I would like to hear some of the other gentlemen.

Mr. Jellett: There is no necessity for an assessment if members would pay their dues promptly. We have been badly handicapped the last few years from the fact that we have been carrying an asset in the shape of moneys owing to the society for dues, which, as a matter of fact, were not an asset. The men whose names were on the roll, and whom we did not have the power to drop until the adoption of the new Constitution and By-Laws, I think had no intention of paying the money. They entered the society under a false impression, many of them. Some of them, I personally know, came in with the idea that it was an adjunct to their business; that is, that they could sell their goods through this society. They found that the society was not intended for any such purpose and they lost all interest in it, and instead of sending in resignations they allowed their names to stay on the roll and their membership to lapse finally when the new Constitution was adopted. That, of course, has handicapped us considerably. As it stands now, there is $195 due from members, and most of that is for dues of 1899. Now with the wiping out of the expense of the summer meeting, which last year was $377, some of this amount will be saved. If the annual meeting becomes what it should become, the amount will not all be saved, because there will be more papers at the annual meeting, due to the fact that we have abandoned the summer meeting, but there will be certainly $200 of that money saved. With $200 coming in and with the $195 now due us we can more than wipe out that deficiency without any assessment, apart from the fact that we wiped out the $215 last year, and I think we can pull through all right. I think it might be advisable, after that matter is discussed, that a motion be made authorizing the new Board of Governors, if they find they cannot meet that expense at the end of three months, to assess the members a reasonable amount—$2 or $2.50, or whatever is needed to make up that deficiency—and that motion simply gives authority to do that after they have tried every way possible. I am not a believer in assessments if we can avoid it. If such a motion were passed the Board of Governors would have an authority which they do not now have and the matter could be straightened out without any further question among

the members. To bring the matter before the house, I would move that the new Board of Governors be authorized, in case of absolute necessity only, to make an assessment on the members pro rata, for a sum equal to the actual deficiency in the society's finances on April 1st.

Prof. Kinealy: It seems to me that while we are considering this matter we should also consider our powers. This, call it what we please, is an increase in the annual dues for this year, and I doubt whether we can do that without probably a two-thirds vote. The motion, it seems to me, should be to give the Board of Governors power to increase the annual dues not exceeding a certain amount—two dollars, three dollars, whatever may be deemed necessary.

Mr. Jellett: Mr. President, we cannot do that, I am sorry to say, under the By-Laws. It requires that for an increase of dues or to make any change in the By-Laws, the matter shall be presented in a perfectly definite form. I do not think it is wise to have a memorandum made that we have amended our By-Laws on a point of that kind, unless we actually needed the money to run the society. I do not think we do. If the figures are compared you will find that we have run the society this past year inside of our net income.

Mr. Thomas Barwick: I think if you simply authorize the Board of Governors to devise means to obtain the money it will be sufficient, without the assessment clause.

Mr. Barron: I am in favor of the motion because I think it gives the Board of Governors the authority, as much as we can give them. I believe that what Professor Kinealy says is correct, that constitutionally there is some objection to it, but the Board could solicit a voluntary contribution from members. That would not be an assessment. The men who are here would certainly give more than the men who are not here.

Prof. Kinealy: Suppose a man gets a notice of an assessment who has not been present; he has not heard the discussion; he knows nothing about the deficit. He says he won't pay the assessment. What are you going to do? You cannot make him pay it. You cannot withhold the Proceedings. You cannot put him out. It is a voluntary contribution, and the word "assessment" should not be used. You cannot make an assessment.

The President: I understand that word is dropped. "Devise means" is substituted for "assessment."

Prof. Kinealy: Mr. Chairman, I am willing to be one of any number here to wipe this thing out, but I would like to see it discussed before a fuller meeting. I therefore move that the motion be laid on the table. (Seconded.)

The motion to lay on the table was lost.

The President: Now, gentlemen, you have heard the motion of Mr. Jellett as it has been amended, to give the Board of Governors the authority to devise some means to wipe out the debt.

The motion was carried.

The President: Gentlemen, the ballot for the election of officers is closed. Is there any further new business?

Mr. Jellett: I move that we adjourn until the evening session.

The President: Before the adjournment I want to announce that the officers and New York members have arranged for a dinner for the members at the Arena, No. 39 West 31st Street, New York City, to-morrow evening at 6.30. The members and their guests will meet in the parlor of this house immediately after the meeting on Wednesday afternoon.

The meeting then adjourned until 8 P.M.

SECOND SESSION.

The meeting was called to order at 8 o'clock on Tuesday evening, January 23d.

The President: The first business of the evening session is the report of the tellers.

Mr. Barron read the report of the tellers as follows:

Total number of votes cast, 71.

For President:	D. M. Quay.....	43
	J. H. Kinealy.....	28
For 1st Vice-President:	A. E. Kenrick.....	53
	Geo. I. Rockwood..	18
For 2d Vice-President:	F. A. Williams.....	36
	Wm. McMannis....	35
For Secretary:	W. M. Mackay.....	64
	Thos. Barwick.....	7
For Treasurer:	J. A. Goodrich.....	65
	H. S. Downe.....	6

For Board of Governors:

R. C. Carpenter	64
John Gormly	55
C. B. J. Snyder	46
D. M. Nesbit	46
Wm. Kent	46
C. F. Hauss	12
J. J. Blackmore	20
A. A. Cary	26
H. A. Joslin	14

Officers elected for 1900-1901:

President, D. M. Quay.

1st Vice-President, A. E. Kenrick.

2d Vice-President, F. A. Williams.

Secretary, W. M. Mackay.

Treasurer, J. A. Goodrich.

Board of Governors, R. C. Carpenter, John Gormly, C. B. J. Snyder, D. M. Nesbit, Wm. Kent.

D. M. QUAY, President.
W. M. MACKAY, Secretary.

The President: Gentlemen, you have heard the report of the tellers. I declare the officers whose names were just read to be duly elected for the ensuing term.

The next business in order is the reading of a paper by Mr. Barwick, on " Neglect of Ventilation in Some Hospitals."

Mr. Barwick read the paper, which was followed by a long discussion.

Mr. Gormly then read a paper on " Dangerous Air Ducts." It was discussed by several members.

After this discussion, Topic No. 1, " What is the best method of connecting open feed-water heaters and exhaust pipes? " was taken up and discussed at length.

The President: Before you leave, I have to announce that the members of the society are invited by Mr. J. W. Jackson, the superintendent, to inspect, to-morrow morning, the heating, electric, and mechanical plants of the Park Row Building. Members wishing to avail themselves of this opportunity will meet at the Park Row Building at half-past ten.

The session then adjourned until the following day at 2 P.M.

On Wednesday morning a visit of inspection was made to the

Park Row Building, which is noticeable as being the tallest office building in the world.

THIRD SESSION.

The meeting was called to order at 2.20 on Wednesday afternoon, January 24th; 2d Vice-President A. E. Kenrick in the chair.

The Chairman: The first matter to be laid before the meeting this afternoon, is the report of the committee to confer with the architects. If that committee is ready, we will now hear their report.

Mr. Jellett read the following report:

REPORT OF COMMITTEE APPOINTED TO CONSIDER THE MATTER OF FIXING DEFINITE FEES FOR PROFESSIONAL SERVICES AS HEATING AND VENTILATING ENGINEERS.

New York, January 24, 1900.

At the annual meeting held January, 1899, after the reading of a paper on "The Relation between the Heating Engineer and the Architect," prepared by Mr. Thomson, the whole subject of this relationship was thoroughly discussed, and as a result of the discussion, Mr. Stewart A. Jellett was elected a committee of one to consider, and, if possible, to formulate a system and schedule of charges by heating and ventilating engineers for services in preparing plans and specifications, and in superintending construction of such work.

At the semi-annual meeting held at Saratoga, July, 1899, he presented a preliminary report, suggested a schedule of charges as a basis for discussion, and asked that the society consider the whole matter and refer it to a new committee for further consideration. The matter was very thoroughly discussed at the semi-annual meeting, and the committee was continued, Prof. R. C. Carpenter and Mr. Henry Adams being added to the committee. Since the semi-annual meeting this committee has been in correspondence with the American Institute of Architects, feeling that whatever arrangement was made should be made with this body, as of necessity heating and ventilating engineers must work with the architects. After considerable

correspondence with the secretary of the Institute, Mr. Glenn Brown, of Washington, the matter was finally brought before the Institute of Architects at their annual convention held in Pittsburg, Pa., November 13 to 16, 1899. At this meeting a resolution was passed referring the matter to the new Board of Directors to be elected at this meeting. After further correspondence, the new Board of Directors took up the matter, and, under date of December 8th, we received a letter through the secretary stating that the Board of Directors had instructed the president to appoint a committee to confer with the committee of our society in reference to the matter of fees. Under date of January 19th, we were advised that at a meeting of the Board of Directors, held January 10, 1900, the president, Mr. Robert S. Peabody, appointed a committee to meet the committee from our society. This committtee consists of Mr. A. G. Boyden, of Philadelphia; Mr. James J. Hill, of Washington, D. C.; and Mr. Walter Crook, of New York City. Your committee recommend that a new committee be appointed at this meeting to carry on this work and to meet this committee of architects at the earliest date possible, so that the matter may be put into satisfactory shape.

The committee also acknowledges with thanks the assistance received from Mr. Wm. H. Bryan, of St. Louis, member of the society.

Congratulating the society on the progress already made, we remain,

STEWART A. JELLETT, Chairman.
R. C. CARPENTER.
HENRY ADAMS.

On motion of Mr. Barwick, the report was received and the committee continued.

The Chairman: The next business in order will be the reading of the paper by Prof. Carpenter.

Prof. R. C. Carpenter read a paper on "Methods of Testing Blowing Fans," which was discussed by Prof. Kinealy and others.

Mr. H. Eisert's paper, "The Calculation of Disk Fans," was read in abstract by Prof. Kinealy in the absence of the author. It was briefly discussed by Professors Carpenter and Kinealy.

It was followed by a discussion of Topic No. 2, "What is the best and most practical method of heating and ventilation for hospitals?" and of Topic No. 3, "Is there a recognized system of symbols for the marking of drawings, for the designation of pipes, ducts, etc.? If not, should not a sign language be adopted for the interpretation of drawings?"

Mr. Blackmore: I am going to move that a committee be appointed to consider this question and bring in a report. I think we will all agree that if some uniform plan of marking the plans could be adopted it would be of very great advantage. But I do not think it can be done without a good deal of consideration on the part of a committee that is well informed on the subject. I suggest that the chair appoint a committee to report at the next annual meeting, giving a recommendation of what, in their opinion, these symbols should consist of. I make that as a motion.

Mr. Jellett: This refers to a standard form of identifying marks on drawings. Why should not the Committee on Standards naturally take up a matter of that kind? I offer as an amendment, that it go to the Committee on Standards.

Mr. Blackmore: I accept that amendment.

The Chairman: The motion before the house is that this subject matter be referred to the Committee on Standards to report at some future meeting. (The motion was carried.)

Mr. Kent: I would like to make a remark or two concerning something that I spoke of a year ago. I said then that the heating and ventilating engineers ought to do something about heating and ventilating this room. You may remember that at that time, although the meeting was no larger than the present one, the air was very foul, and if we attempted to get any in from the skylight overhead, it came down on the top of our bald heads and chilled us. There has been since then a remarkable improvement. The Secretary of the Society of Mechanical Engineers considered all the different ways that were proposed, of having exhaust ducts, exhaust fans, and so on, to get fresh air in and the foul air out, and he proposed to put a coil of pipe up there in the skylight to heat the cold air that came down on the top of our heads. But the happy thought struck him of putting in these panes of glass, making a complete glass floor under the skylight, leaving a small opening in every other pane. Pre-

viously that whole space around the outside where these clear panes of glass are was open. The result was that the air in this room went up and got chilled against the skylight glass and then came down on our heads. Now he has prevented the descent of cold air on the top of our heads by means of these panes of glass, and we get sufficient fresh air through the small openings. I am informed that the expense of the alteration was only $23.

On motion, the meeting adjourned until the following day at 10.30 A.M.

FOURTH SESSION.

The meeting was called to order at 10.50 A.M. on Thursday, January 25th.

The President: The first paper to be read is a paper by Prof. Carpenter, on "Condensation of Steam in Blower Systems of Heating."

Prof. Carpenter then read the paper, which led to a long discussion by several members.

This was followed by the reading and discussion of Mr. Albert A. Cary's paper on "The Removal of Dust from Boiler Rooms."

Mr. Barron: I move that we adjourn.

Mr. Jellett: Before we adjourn I want to offer a motion. That is that the thanks of this society be extended to Mr. J. W. Jackson, the superintendent of the Park Row Building, for his courtesy in showing members of the society through the building yesterday.

The motion was seconded and carried.

The President: Before the motion is taken on the adjournment, I would like to ask the consent of the meeting to making a change in the programme. It is impossible for me to be here this afternoon, and I would like, therefore, to ask that the officers be installed now instead of at the afternoon meeting.

Mr. Barron: I move, Mr. President, that we proceed with the installation of officers. (Seconded and carried.)

The President: Before proceeding with the installation, fellow members, I want to thank you and also the officers for the assistance you have given me during this meeting, and I only regret that I have not been able to do more for you than

I have done. But I will continue to further the interests of the society when I am back in the ranks. That I can promise you.

Gentlemen, it gives me pleasure to introduce to you our friend, Mr. Quay, whom you have elected president.

Mr. President, I turn over to you the society in good order and knowing that you will have the support of the officers and members as I have had it.

Mr. Quay then took the chair and addressed the members as follows:

I think it is quite fortunate for me and the society that you have decided to install the officers at this time, because there is no time for a speech and I do not think you would like to take up the time now to hear any speech. I would like to say just a word or two. First, I thank you very kindly for the honor you have conferred upon me, and I feel quite embarrassed in taking this position, and were it not for the able men you have selected on the Board of Governors, and the other officers, I am sure I would not feel able to take the position and assume the responsibility. I think you have made a mistake, but I will do the best I can to fill the office acceptably and to help to make our society a success. It will not be possible for the Board of Governors and officers to carry on the work of the society without the support and co-operation of all the members. That, of course, goes without saying. I feel that our society is becoming recognized as one of the leading societies of engineers in the country. We noticed last night in one of the speeches at our banquet a gentleman said that some of the architects are finding it necessary to have the heating and ventilating apparatus erected and then put up their building to suit it. So you see the architects are recognizing the engineers, and I think that our society deserves credit for the recognition we are receiving. The American Institute of Architects has appointed a committee to confer with a similar committee from our society to consider the relation of the architects and engineers. The Commissioners of the Paris Exposition have also recognized our society by appointing one of our members on that Commission. We have a large field to occupy and a great work to do. When we consider that our society is young, that it was only organized in 1894, and we look over the work that has been done by the society, I think we may well feel encouraged. I hope that every member will put his

shoulder to the wheel and do his part in furthering the interests of the society, in assisting the Board of Governors and officers in their work, and let us make this, if possible, the banner year of our society and go forward in this good work, and the victory is ours. (Applause.)

The president then introduced the 1st Vice-President, Mr. Kenrick, and the 2d Vice-President, Mr. Williams, and the secretary read the names of the Board of Governors.

Secretary Mackay: The Board of Governors consists of the President, D. M. Quay; Prof. R. C. Carpenter, John Gormly, C. B. J. Snyder, D. M. Nesbit, William Kent, and W. M. Mackay.

The president then introduced to the society those members of the Board of Governors who were present.

The President: After the meeting adjourns we wish to have a meeting of the Board of Managers, the Council, and the new Board of Governors. We would like to have a short meeting.

An adjournment was then taken until 2 P.M.

FIFTH SESSION.

President Quay called the meeting to order at 2.40 on Thursday afternoon.

The President: The first business for this afternoon's session is the reading of a paper on "The Rating of Steam and Hot Water Boilers for Heating Purposes," by James Mackay, member of the society.

Mr. James Mackay then read the paper, which was discussed by several members.

Topic No. 4 was then discussed. It was "When heating by direct radiation, should the radiators be placed close to an outside or an inside wall? And if placed on outside wall, should they be placed between or before the windows?"

This was followed by a discussion of Topic No. 5, "When testing radiators, what should be considered the maximum allowable error in any one test of a series?"

The President: Before proceeding with the next topic of discussion, the secretary has a letter from Mr. Waters, of Chicago, which he will read.

Secretary Mackay: I would state in connection with this letter, that in the last circular letter sent to the members at the

request of the Board of Managers, reference was made to the Paris Exposition, and this is a reply to it, or rather an addition to it, by Mr. Waters, the chief engineer of the Board of Education of Chicago. He wrote to me some time ago in reply to our circular letter, that he would have something prepared later to go with our exhibit.

The letter is as follows:

BOARD OF EDUCATION,
OFFICE OF CHIEF ENGINEER,
CHICAGO, January 23, 1900.

William M. Mackay, Secretary, American Society Heating and Ventilating Engineers, New York.

Dear Sir:—I have in my office, ready for shipment, an Isometric Projection of a heating and ventilating plant in the George Dewey School Building in Chicago, together with some photographs of constructional work. Similar copies have already been sent to the Paris Exposition to be used in the Educational Department set aside for the City of Chicago.

If you think they would be of interest to our society exhibition at said exposition, advise me, when convenient, how to forward them to Mr. Wolfe, and oblige,

Very respectfully,

T. J. WATERS, Chief Engineer.

The President: How shall we answer Mr. Waters's question? Has any member any suggestion to make?

Mr. Joslin: I move that the matter be referred to Mr. Wolfe.

Mr. Wolfe: Mr. President and Gentlemen:—My instructions were to solicit exhibitors for the department, and they are very rigid. There have been certain charges in part borne by the government and part must be borne by the exhibitors. We are simply furnished with space, not even a floor. We have to build our own floors, our own partitions, and everything of that kind, and the government money has not anything like held out. So, there has been a charge made to each exhibitor, and your representatives have not been allowed to deviate from it in any way. I regret very much to say that our ventilating department is conspicuous by its absence, almost. We have apparatus of all kinds, but nothing in its entirety which would show a complete ventilating apparatus as it should be shown, and be up to the

American standard. The nearest we have approached to it is an exhibit of drawings made by the State of Massachusetts. I should be more than happy to do anything I could to bring the society into prominence and do for it what I could in the exhibition. If we can get in we will be entered as a matter of record in all French documents and American documents, and documents of all other countries in matters of reports; certainly, it would benefit our society and bring us into prominence. If you gentlemen will kindly appoint a committee with whom I can consult in New York, I will make it my business to-morrow to consult with the Commissioner and gain whatever concession it is possible to gain. I think we are entitled as a society of engineers to make an exhibit without paying the charges that the manufacturer could afford to pay, because to him would accrue a profit. We, of course, are not looking for a profit. It is simply to show the advance of the art in America. I would supplement that by saying that if a few of our members would eliminate their individualities for a little while and submit a drawing, possibly with the name of the society upon it, I would endeavor to have it put in a portfolio and exhibit it. My privileges are not many, but anything that I can do to get it in for nothing, or practically nothing, I should be very glad to do.

Mr. Kenrick: In view of the remarks made by Mr. Wolfe, I move that the subject matter be referred to the Board of Governors, with full powers.

The motion was seconded and carried.

The President: The Board of Governors has appointed an executive committee of three, and this matter will properly come before that committee. They are all New York members, and can meet with Mr. Wolfe at any time. The secretary will inform Mr. Wolfe.

We will now proceed with the discussion of the topics. Topic No. 6 is: "Does the present construction of large buildings with curtain walls made of hollow brick and plastered, conserve the heat as well as solid brick walls, furred, lathed, and plastered?" Is there any discussion on this topic?

None of the members present were prepared to discuss this topic.

The following topics were then presented, and each led to a very brief and unimportant discussion.

No. 7. "In heating factories, is it wise to use only direct radiation without ventilation, or would it be better to use a forced circulation of warmed air?"

No. 8. "What is the most efficient and economical manner of taking care of drips from steam systems where the condensation is not returned to the boiler by gravity?"

No. 9. "Cannot a schedule be devised for the proper ventilation of toilet rooms in public buildings, doing away with deodorizing appliances."

The President: I will ask the secretary to read the names of the members who have been appointed on the standing committees.

Secretary Mackay: The president has appointed the following committees:

Compulsory Legislation: Henry Adams, B. H. Carpenter, T. B. Cryer, A. Harvey, T. J. Waters.

Uniform Contract and Specification: John Gormly, A. E. Kenrick, H. J. Barron, F. K. Chew, R. P. Bolton.

Standards: Prof. J. H. Kinealy, J. J. Blackmore, Herman Eisert, H. A. Joslin, Wm. McMannis.

Tests: A. A. Cary, B. F. Stangland, Wm. Kent, C. M. Wilkes, Jas. Mackay.

The President: We have finished the programme. What is the wish of the society?

Mr. Barron: I move that we adjourn, Mr. President. (Motion seconded.)

The President: I wish to thank the society for the courtesy it has extended to me, and I hope that we may have a very successful year.

The meeting then adjourned.

The following members and guests were registered as being present during the meeting:

MEMBERS.

Henry Adams.	R. C. Carpenter.	T. B. Cryer.
H. Addams.	A. A. Cary.	W. H. A. Davidson.
H. J. Barron.	F. K. Chew.	W. A. Dunn.
T. Barwick.	G. B. Cobb.	A. C. Edgar.
J. J. Blackmore.	F. L. Connard.	A. H. Fowler.
E. J. Brooks.	J. A. Connolly.	J. A. Goodrich.
B. H. Carpenter.	A. A. Cryer.	J. Gormly.

W. S. HADAWAY, JR.
R. HANKIN.
A. HARVEY.
S. A. JELLETT.
H. A. JOSLIN.
WM. KENT.
A. T. KELLOGG.
A. E. KENRICK.
A. S. MAPPETT.
W. M. MACKAY.
JAS. MACKAY.
H. C. MEYER, JR.
W. H. MCKIEVER.
GEO. O'HANLON.
A. E. PAUL.
J. A. PAYNE.
D. M. QUAY.
H. H. RITTER.
L. B. SHERMAN.
H. A. SMITH.
B. F. STANGLAND.
H. W. SWITZER.
E. P. WAGGONER.
J. R. WENDOVER.
F. A. WILLIAMS.
W. F. WOLFE.

GUESTS.

C. ANDREWS, Hartford, Conn.
L. W. ATWATER, New York.
P. E. BARBOUR, Boston, Mass.
F. G. BLODGETT, New York.
W. M. COSGROVE, New York.
J. DUNCAN, St. Louis, Mo.
C. F. FROST, New York.
H. B. GOMBERS, New York.
A. G. HALL, New York.
H. HOVEY, New York.
G. H. KOVEN, New York.
L. O. KOVEN, New York.
A. J. MURPHY, New York.
W. W. MACON, New York.
E. RUTZLER, New York.
C. F. WEST, Philadelphia, Pa.
T. H. WILLIAMS, Jersey City, N. J.
E. T. WEYMOUTH, Brooklyn, N. Y.

PAPERS

OF THE

SIXTH ANNUAL MEETING,

New York, January 23, 24, 25, 1900.

LXX.

NEGLECT OF VENTILATION IN SOME HOSPITALS.

BY THOMAS BARWICK.

(Member of the Society.)

In many hospitals, built some years ago, there were few attempts at ventilation, the warming being accomplished by stoves or direct-steam apparatus; but within the past few years, the benefits derived from well-ventilated buildings have induced most of our private hospitals to provide for a fair allowance of air supply.

A few of the older hospitals in New York and vicinity were supplied with direct-indirect, or indirect steam heating, with vent flues to exhaust the vitiated air.

The ventilating apparatus was usually dependent upon the conditions of the weather. Tempering coils, or gas jets, were used in the aspirating shafts, and, in a few cases, fans were supplied for mechanically moving the air.

Some of the apparatus in hospitals has been kept in good order, but much of it has been allowed to fall into decay.

In one hospital that I was called upon to investigate, I found a direct-indirect apparatus for heating and air supply, which, for lack of sufficient heating surface, had all of the cold-air inlets closed off.

The ventilating registers were very small and placed about 10 feet above the floor. The two boilers were large enough to do what was required for the building, providing the cold air supplied to the radiators was checked. They may have been large enough to do all the work originally planned, but there had been an addition placed on the building, which was not fitted for ventilation, but supplied with direct radiation; an out-building had also been added, and the heating of it was also crowded on the boilers, besides the cooking, the laundry, and

one elevator. The vent shaft was built adjoining the smoke-stack, the two being carried up together, so as to give the appearance of a tower.

The vent registers on the different floors were connected into common vent flues, brought down to the sub-basement, and galvanized iron branches were carried from them over the floor into a trunk main duct, made of galvanized iron, which was carried along the centre of the building on the floor, and thence into the vent shaft beside the chimney.

The foot of the vent shaft had a rise above the sub-basement floor, and the galvanized iron duct was carried up on a slope and connected with the bottom, flush with the vent-shaft floor.

The exhaust pipe from the elevator engine was carried into the vent shaft just above the vent duct, and carried to the centre with an open end.

The engines on the elevator machine were of the old oscillating style, and the water carried over in the exhaust caused a damp duct, by draining into it.

The drips from the cylinders were not connected in any way that would properly clear the cylinders.

The hospital was erecting a new wing to the building, and I was requested to find out if the two boilers would take care of the new wing, which was to be warmed by indirect radiation and ventilated by aspirating flues, together with the present buildings and apparatus.

In my report I requested them to change the old plant, and put in at least one larger boiler, and two if possible.

I designed a boiler-house, and set one boiler connecting into the old chimney, which was of good area, leaving space for an additional boiler.

The old system I placed under 35 pounds pressure through a reducing valve, and trapped the returns, with the understanding that as soon as sufficient money was raised, the old apparatus should be rearranged, and a proper ventilating scheme adopted.

After starting up the new boiler and getting everything in working order, we had the old boilers discontinued, and, after much difficulty, the hand-hole plates were loosened and taken out. The sight of the accumulated scale was frightful. I don't believe the boilers had been blown out or cleaned in years. We chipped off some of the scale so that there was a passage for cir-

culation of the water between the tubes, and as the boilers were about 20 years old, we did not care to chip too close to the tubes. We left the boilers as an auxiliary to the new plant.

Repeated washing and using of crude oil and cleaning gradually removed some of the scale, which bettered the condition of the boilers; but we were always fearful until the additional boiler was set.

This is the way some plants are kept, and when the apparatus begins to go it goes all at once, and costs a deal of money, which might have been saved if proper care had been taken to keep the plant clean and in thorough repair.

I found in another hospital a similar lack of care, but of much more particular apparatus.

A ventilating plant was put in to introduce tempered and hot air into a part of the building, by means of an electrically-driven fan, and a proper exhaust ventilation arrangement was made to discharge the vitiated air.

The inlet registers were placed near the floor, discharging across the room, and the ventilation was through grills located near the floor and registers with vanes near the ceilings in most of the rooms, and central ceiling registers in other rooms where not practicable to place them in the side wall.

The fan chamber was placed in the sub-basement. It was built of brick in a substantial manner; the floor was concreted, so that it could be flushed with water and cleaned; by-pass dampers were placed in a wall beneath the coil, and the coil was set so that the air would be tempered, with auxiliary coils placed to raise the temperature in some rooms if desired.

In order that pure fresh air should be introduced, there was placed a cold-air shaft running up about 25 feet above the grade. The plant was fairly well designed, and erected in accordance with the specifications made by the architect.

There was no damper in the cold-air duct. The supposition was that the plant was to be operated continuously, and a damper was not specified; but it would have been a good thing if used judiciously.

The coil in the chamber was built in sections, so that various degrees of heat could be imparted to the air, the steam pressure being about 5 pounds, regulated by reducing valve and by-pass, one section being arranged with separate connection, so that

high-pressure steam could be used, to further increase the temperature. Thermostatic regulation was attached to the coil as a further precaution to have it work nicely.

Everything was put in good order and left satisfactory. I visited the same place a year later, and I found the reducing valve shut off, and high-pressure steam blowing through all of the coils, which were baking hot.

The thermostat was disconnected, gauges broken, the fan at a standstill, the motor dirty, the doors banged and bent at the bottom, the mortar and brickwork broken away, and the cold-air shaft blocked up with wood and bagging; the fresh-air supply, passing through the coil, being taken from a dirty sub-cellar.

In another place I found an old scheme of ventilation, carried up into the attic with ventilators on the roof, and pipes carried to drums beneath the ventilators.

The doors of the drums were rusty, and some were broken off, and there was nothing, in the shape of aspirating coils, to induce the air to flow.

A new heating system was called for in a specification, but no provision was made for the supply of fresh air to assist the ventilation.

The vertical flues were 10 by 12 inches, and the connection to the drums was 12 inches. In many cases they were found broken and lying in the attic. Each of the vents served wards containing three to four beds, the registers being placed near the ceiling.

In another place I found no provision for ventilation, but a worn-out direct steam-heating system with considerable leaks. A specification was being estimated upon to introduce a new direct-heating apparatus, but no ventilation was provided for.

In another I found the main building and two wings with a sub-basement tunnel, carried through the wings; and an old air duct with circular spaces, where, at one time, had been placed furnaces, which had given some supply of air. These trenches and tunnel were filled with old refuse and dirt of years' standing. The direct-heating apparatus had numerous patches, additions, repairs, and botchery, with some new modern inventions added, but there was no ventilation. The rooms and wards were crowded, until the porches and veranda had been glazed and

filled in, to admit of more beds being placed in the institution. I feel that this Society should agitate the proper ventilating of hospitals, and insist that the health departments in all cities or counties should demand at least 30 cubic feet of air supply to each patient, and make that a minimum—warmed to a temperature of 70 degrees in winter—and that sufficient apparatus should be furnished to supply that quantity during summer weather. Many new buildings are supplied with apparatus of this kind, and all, both old and new, should be brought up to that standard.

DISCUSSION.

Mr. A. A. Cary: Mr. President, I had not received this paper previous to coming to the meeting this evening. The subject is a very interesting one and leads me to put before you a little experience of my own last summer, which will only confirm and add to what Mr. Barwick has already said:

During the past summer I was retained to examine the heating and ventilating plant of a hospital near New York where considerable trouble was experienced. The complaints might be summed up thus:

The hospital could not be kept at a comfortable temperature during very cold weather.

The amount of fuel required and used seemed excessive.

The ventilation expected from the system installed was not realized.

In most of the rooms or wards windows had to be opened to admit fresh air.

During moderate weather it was impossible to regulate the temperature, the rooms and wards becoming overheated, again necessitating the opening of windows.

I found the heating and ventilating, as well as the steam and electric plant, in charge of an engineer who had held this position for less than a year; and, whereas he understood his boiler, engine, and dynamo pretty well, the system for heating and ventilating the building was evidently a mystery to him.

For heating the main building I found a series of seven iron stoves arranged in a chamber in such a manner that the incoming air would rush over one, two, three, or more of them (this being

controlled by dampers) as it passed on to the ducts supplying hot air to the various parts of the hospital.

This air was drawn from outside through a cold-air flue, having an unprotected entrance but a few feet above the yard level.

A centrifugal pressure fan was placed in the basement with its driving dynamo, and arranged to receive the air it handled through this cold-air flue, and then discharged it over the iron stoves and beyond, through the hot-air ducts which distributed it to the various rooms, halls, and wards of the hospital.

The discharge outlets of these hot-air ducts were registers (opened and shut by hand) placed near the ceilings.

An equal number of outlet registers were placed near the floors, and all the vitiated air was supposed to escape through these lower openings, which were connected by ducts to three ventilating chimneys terminating above the roof. All of these exhaust ducts from registers were connected with several large mains running along the ceiling of the basement, at which level they were connected into the chimneys.

When holding an open handkerchief in front of these exhaust registers I failed to discover the slightest movement of air through them, and a few tested with hanging threads failed to develop other indications. So little did the hospital attendants understand the purpose of these lower registers I found that they had moved cabinets and other obstructions in front of many of them, so as to completely destroy their purpose even had they been effective.

Further investigation showed shallow, contracted, and tortuous ducts connected to many of these outlet registers, and after tracing these ducts to their respective chimneys I found there most startling revelations. One of these chimneys, located near the engine room, had a large disc fan at its entrance, which had not been turned over for a long time. The engineer said that he had run it for a short while, but thought that it did no good, and so he had discontinued its use. I found no fans at the entrance of the other two chimneys, but the exhaust mains were simply entered on a level with the basement ceiling.

This I could not understand, but, after diligent inquiry, found that there were two stoves lying in the basement, and the engineer could not conceive what they were there for. I then found that these had been intended for the lower part of these two

stacks to create a draft, but, as far as I could learn, they had never been used, so the uselesness of the air outlets in the rooms was to a large measure explained.

Going back to our air supply. As stated above, the cold-air inlet (which was but a few feet above the yard level) was not in any way protected. In other words, no provision was made to screen the air before it entered the hospital, and, therefore, the flying dust and outside impurities entered this system and were forced by the fan into the different halls, rooms, and wards; an evidence of this being plainly visible upon the white side walls surrounding the upper inlet registers, where in every case a splashing of dirt could be seen radiating in every direction.

The engineer was quite eager that I should understand that in very cold weather he had to work hard to keep up his fires in the seven cast-iron stoves which heated the inlet air, and he told me further that these stoves had to be kept red hot at such times, and even then did not succeed in supplying sufficient heat to the building.

What a surprising condition of affairs this was to find in a supposedly modern hospital building, not five years old, located within a radius of thirty miles of New York City.

Further investigation discovered a small vertical boiler of about ten-horse power in the basement of the building, entirely disconnected from the chimney and also from the system of steam piping, and otherwise dismantled. It seemed that when another building, which was used as a maternity hospital, was erected (located near the main hospital) it was determined that this building should be steam heated, and, therefore, the small upright boiler just referred to was put out of service, and a second-hand Babcock & Wilcox boiler of sixty-two horse-power was found, purchased, and erected in the basement of the main hospital. The small boiler was formerly used for supplying steam to the laundry, steam tables, and water-heating apparatus, and also for running a tank pump.

When the new boiler was erected its steam was used for the above-named purposes and also for heating the maternity hospital, by use of a Sturtevant fan and steam-coil system, and it also heated several small outlying buildings by direct radiation.

A direct-connected dynamo and engine was also installed, supplying electric lights to the place, the current having been for-

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merly taken from the electric light company's mains. The steam for this engine was also taken from the new boiler.

Notwithstanding all these uses for steam supplied by this boiler, it was almost twice the required size under maximum conditions, and, therefore, was being operated wastefully, due partially to the upper firing door being open a great part of the time, admitting much cold air to the heating surface.

You will see that in order to operate this plant it was necessary to run seven separate fires in the seven stoves placed in the path of the entering air. Two other stoves should also have been kept in operation at the foot of the two ventilating chimneys, having no fans to create a draft. And, besides these nine separate fires, it was necessary to operate the tenth one in the furnace of the boiler, and with this information it certainly was not surprising that an excessive amount of fuel was used.

A source of further trouble was discovered, due to the water supply of the hospital. This water was taken from a driven well and was very hard, showing a considerable percentage of lime and magnesia on analysis. The use of this water gave endless trouble in the laundry, where it was impossible to get satisfactory results, to say nothing of the amount of soap it wasted, and in the boiler this water gave a great deal of trouble, where it caused scaling and required occasional removal and replacing of parts, and under such conditions it was surprising to me that, having an extra boiler as they did, it was not put in serviceable condition, to be used in case of accident to the larger boiler.

With the above conditions before me there was very little trouble in suggesting the best method for improving this plant. I recommended the discarding of the nine iron stoves and the substitution of a steam-heating coil for the seven stoves used for heating the air supplied to the hospital. I also suggested a method for utilizing the exhaust steam.

The exhaust fan in the heating chimney above referred to was to be kept in operation continuously both winter and summer, and I further recommended the placing of other fans, in a similar manner, at the base of the two chimneys, to be driven by electric motors, the current being taken from the generator they then had in place. These fans were also to be operated winter and summer. The pressure fan was also to be operated in the summer, over the cold pipes of the heating coils, to supply fresh air

throughout the building. By this means, you will see that but one of the ten fires before mentioned was needed for the operation of this plant.

I further proposed a system for screening all air admitted to the hospital, so as to secure a pure supply, and as this precaution had been also overlooked in the maternity hospital I proposed that it should be introduced there as well.

I further insisted upon the necessity of placing this spare vertical boiler in service as soon as possible, so it could be used to its greatest capacity in case of breakdown of the main boiler.

And, lastly, I proposed a system of purifying the water taken from this driven well, which, by proper treatment, could have practically all of its harmful impurities removed at a cost of not over one cent per thousand U. S. gallons, and the cost of this purifying plant completely installed would not exceed $850. The process I suggested was a modification of the old Porter-Clarke process of chemical purification, such as has been used in England for the last twenty-five years.

Mr. John A. Payne: These gentlemen have just been speaking about apparatus which is at least five years old. During the past year I was called upon to figure for installing an apparatus in a hospital in New Jersey, where our secretary hopes soon to secure some legislation that will compel owners of buildings of that character to provide proper ventilation. The specification called for a direct hot-water heating system. I figured on it and was the unfortunate one to get it. When I had secured the contract I tried to induce the contractors to change it and put in an indirect system. I told them that it was criminal to put the apparatus in as it was, but when I told them about the probable additional cost they were frightened. I therefore had to install the apparatus as specified. There were twenty beds in each of the wards and some private wards upstairs. There is no provision for ventilation, and to insure that the patient will be thoroughly comfortable, they have put on double windows. This is just a bare statement of what is going on to-day. You all, doubtless, know it, though perhaps none of you have met during the past year anything quite as bad as this. In this case there was no attempt at all at ventilation and no apparent appreciation of it by the managers of the hospital, who would not spend the few extra dollars necessary to provide pure air for the patients

they are trying to restore to health, but whom in reality they are almost killing.

Mr. Stewart A. Jellett: Mr. President, this paper of Mr. Barwick's touches on two things: one is the improper design at the present time of heating and ventilating systems for hospitals, and the other is the improper operation of existing plants. I do not think there is any doubt but that every one of us that has had any experience in hospital work can testify to plants that were designed to be run in a certain way, and after a very short period have been run in an entirely different way, and the committee of the institution know nothing of what goes on in the boiler house or below the first floor level. I have done a great deal of hospital work in different parts of the country. I have had to do with some of the best plants in the country and I have inspected and patched up some of the worst. I might relate three or four cases to give you samples of what is done under the direction of medical men who are presumed to know better.

The first one is a group of buildings in a hospital. Two buildings of the group have been erected in the last two or three years and are modern in every respect. The building that lies between these two is a building some eight years old. It has in it an indirect system; a fan for the supply of air, with tempering coils. I made an examination of these buildings with the idea of connecting all of them to a central power house. On this inspection I was accompanied by three of the doctors who were members of the Board of Trustees. I saw the trunk line ducts from the blower system passing along the ceiling through the kitchen. They were bruised and battered and joints broken. Through the morgue I found the same thing. I went through rooms where they stored their garbage barrels ready for the wagons to take them away. I finally brought up at the fan. I said to one of the doctors, "I presume the fan is in this room?" He said, "Yes." I could hear it at work. I said, "Where does the fan get its air supply?". "Through the window," was the answer. I said, "I would like to get at that window." He said, "It is just behind that door." I said, "I have been here before and have tried to open that door but I could not do it." "Well," he said, "we will have it pushed open; I don't think it is locked." After using considerable force we pushed the door open. It was held by two barrels full of garbage. The fresh-air room was

filled with empty oil barrels—anything that was wanted out of the way and out of sight. The window through which the fresh air came was taken from an alley which had actually, if both sashes were open, about sixteen square feet of air; but in the position in which I found it, with only one sash open, it had about three square feet of opening. The air was drawn over these empty oil barrels through all this rubbish to the fan. It was then carried through this duct and carried to the patients above after it had passed through and over all this. Yet the same committe had, only the year before, passed on a plant that was up-to-date in every respect, and they admitted, when I called their attention to it, that they had never seen that room before. They had been on the Board for some years. That is a sample of one hospital. They told me that they presumed that the chief engineer was familiar with everything about the plant. I asked the chief engineer about it. He had been there about two months, and he said he had not assistants enough to cover the ground and he simply could not attend to everything; that was all there was about it.

I went to another hospital some time afterwards where they had recently added two new buildings. I was asked while I was there to inspect the old hospital. I went up into the wards. I found the fresh-air inlet registers covered with muslin carefully pasted down with flour paste. One of the nurses told me it was to prevent cold drafts and unpleasant odors. I said, "What do you mean by unpleasant odors?" She said, "It is very disagreeable, to say the least." I found the same state of things in nearly all the rooms. I followed down the system to the basement. I found an underground brick duct that led to an aspirating chimney in which there was an aspirating coil, but the connection had been frozen years before, from all the evidence, and had been broken. There was no steam on, and in the recollection of the engineer, who had been there for six years, there never had been, so that the air naturally would not go down and pass the horizontal duct 300 feet long to reach that aspirating shaft. The shaft itself was wet and the underground duct was wet and very foul. It had not been cleaned. The result was that the circulation was down through the short aspirating chimney, through the underground duct and into the wards. The committee was perfectly willing to spend money to have the plant put

in right, but they never thought it their business to look at it afterward or even inquire about it. I found they had three boilers of 60 horse-power. They were burning five tons of coal a day and could not keep up steam enough. They were carrying 60 pounds of steam on the radiating surface. I followed it through and found that the returns came back to a well in the boiler-room which had a vent-pipe to the roof, and the cloud of steam coming out of that would have run the hospital. The result was that they were burning from five to six tons of coal a day.

I have another hospital in mind which is a hospital for consumptives. The system there has been well designed and well put in, but the chief physician is what I would call a crank on ventilation. In spite of all the rules and directions given him by the Board, who were very much interested, he insists on opening the windows half-way down and blowing fresh air through those rooms until they drop to a temperature of about 45 degrees. He says, " Wrap the patients up in bed and give them the fresh air." I have talked with him a number of times about it and so have the President of the Board of Trustees and one or two of the Committee. He says he is right, he knows what he wants, and if the patients stand it I guess they will continue to get it. The ventilating system is there, he admits it works, but he thinks that his way is better.

I then visited a hospital in Baltimore. It was a question of erecting a new building and I examined the old building which was to be attached. In the basement of that building I found old mattresses, old bedding, everything mouldy and forlorn; it was a storehouse for the dumping of the entire hospital—the clothing from pauper patients, colored people, that came in there. The whole place was simply filled up with stuff of that kind. Old straw mattresses were decaying in the basement. There was a single floor of one thickness of boards between that and the wards. The air in the cellar was enough to gag you. I could not stay there very long. I guess the President of our Association has been in the same cellar. And yet the men who are responsible for that are not the men who designed the heating or ventilating plant. It is the doctors and the men on the Board of Trustees who are presumed to operate it. I think we cannot be too strong in bringing out that side of the question.

It is all very well to design and have built a proper heating and ventilating system; but if it is never used, it is a waste of good money and it does not help the profession in any way that I can see.

Maj. Henry C. Meyer: I would like to make a suggestion to the society, if they care to follow it up, and that is when attention is called to these cases of bad management, if they can see their way clear to report such hospitals and the names of the superintendents of the hospitals in such a manner that the facts can be verified and published and quoted by the medical journals and local papers in the vicinity of those hospitals, that that is the only way by which you can bring public opinion and public criticism to bear upon the men who are responsible for the conduct of these hospitals and for the outrageous condition of affairs existing in them.

As the founder of "The Engineering Record," I frequently had my attention called to cases of this kind, especially in the early years of the paper. The difficulty was to obtain consent to make use of the information. The gentlemen who obtained the information, through doing work in the buildings or being asked to make a report, as these gentlemen have done, felt that they could not make the matter public. It affected them either commercially or professionally. Now, in order to avoid that difficulty, I would merely make this suggestion: that a committee might be appointed to report upon certain cases, and mention the hospitals and who the officials are. I did that once some fifteen years ago, in the case of the Packer Institute in Brooklyn. The daily papers took it up. The "New York Times," for instance, claimed that the building should be razed, and scored the trustees. The school came near being closed. The medical press throughout the country quoted the articles. The result was that the system was examined and a new system was put in, costing some ten or twelve thousand dollars. Of course, I have no knowledge as to how it was maintained afterwards, but as Mr. Jellett said, after a modern plant is installed, it certainly is absurd to suppose that any reform is going to come by simply relating the usual experience with incompetent engineers who are trusted by the doctor in charge. It is the doctor in charge of the hospital whose name should be published, and the hospital. After a few proceedings like that you will find that there will

be some reform. If it cannot be done by the society, then I suggest that the Board of Health of the State be asked to make investigations, and report the result of their investigations. Then there will be some appreciation of the value of a ventilating plant. There will be more demands to have them put in, and there will be some public education on the part of the people who pay for these things and are supposed to have a voice in their adoption.

Mr. Barwick: Mr. Meyer's speech is in confirmation of what I have said, practically. I made the request that the matter be placed in the hands of the Health Boards. I think the Health Boards are the people to treat this matter, and they can do it better than any one else, if they know of these things, or if these things are brought directly to them. But it is not a contractor's place to go and complain of things of that kind. I went there simply as a contractor. I find that most of the private hospitals are better kept than those that are controlled by the city. The trouble with most of our city hospitals is that they are controlled by men that have no knowledge of engineering and no knowledge of the plant that they have to care for. Those officials will last probably for a year, or until another administration comes in, and then they are discharged and others take their places. Two or three of these institutions that I have spoken of are hospitals right within this district; one of them has been before the grand jury of Brooklyn.

Major Meyer: The superintendent of the hospital is the only man that should be held accountable in every case, like the captain of a ship. It is his business to know what his engineers are doing, and what they are putting in the cold-air shaft, and if he does not make a periodical inspection and look after that, he cannot expect men hired for $2.50 a day to look after it.

Mr. Barwick: Yes, but they don't have the money to give these people sufficient help. At one of these hospitals I speak of, there was but one engineer with a couple of hangers on.

Major Meyer: He has money enough to put his garbage somewhere else than in the cold-air shaft.

Mr. Barwick: The garbage barrel was not in that. But, unfortunately, it was something as bad. I found the tunnel under the main building. I found it full of old barrels and old bags and old clothes. The dust was pretty thick. So, I don't

believe that the man had ever been in there since it was put in. It was away down out of sight and out of memory.

Mr. Jellett: I want to relate one case that is directly the opposite of what we have been talking of, as an example of what a man should be as chief engineer. I will name the hospital, so that you will know that there is one man who attends to his business. I presume he is still there. About a year ago I went to the Presbyterian Hospital in New York, to examine an electric light engine. I was referred to the new engine put into that building, and I wanted to see it in operation. I went to the building, found my way through the office down to the chief engineer. They told me that I had better deal directly with the chief engineer. I found the engine and boiler-room, a couple of firemen at work, everything looking as clean and nice as possible. I had never seen a cleaner engine room in my life. I inquired for the engineer; they said he was around somewhere, and that it would be better for me to wait right there instead of going around and trying to find him. After waiting about twenty minutes, a man apeared with a suit of overalls on and an anemometer in his hand, and a water gauge. The fireman said: "That is the chief engineer." I stepped up to him and introduced myself. I said, "What are you doing with that anemometer and water gauge?" He said, "I have just been crawling through the underground ducts and tunnels, making some tests." "How often do you do that?" I asked. "Every week," he said; "I go through every underground duct and tunnel that I can crawl through. I examine its condition and the air currents and its pressure." He is the first man that I ever saw that did that. I told him that he was the first man I ever saw who attended to the ventilating plant in a hospital, and I said: "I hope the hospital authorities appreciate it." Every piece of machinery was working to perfection the day I was there. I inquired afterwards from the man who put in the engines. He said, "I am always glad to refer people to my engines in that building because I know they are in good condition." But you do not find very many places like that.

Mr. John Gormly: I think we ought to look at both sides of the question in this matter. As engineers, we would naturally look at the engineer's side of it. But I think almost every question has two sides. I have visited a great many institutions

where heating apparatus is used, and I find that it is very rare to find an institution in which the engineer has directions which are clear, so that the men who are unskilled, not supposed to be familiar with all the details of a modern apparatus, will be able to run it. I think that is a point that ought not to be overlooked. It seems to me that there should be clear, explicit instructions. There should be an explanation of the system printed plainly, so that the engineer or the man in charge can understand thoroughly what is expected of the apparatus, and I think with ordinary intelligence on the part of the engineer, you would get very much better results in many of these plants. The trouble is, the men in charge do not know how to run them. They never studied the science of engineering, of heating engineering particularly, and they do not know what is expected of the plant or of the machinery or system at all. They do not understand it. That is where I think we are to blame, in a certain measure.

Professor Kinealy: It seems to me that we ought not to confine all our attention to the engineer. I am sure from conversations that I have had with physicians, that there are many of them who might be educated with great advantage to the public. There are many physicians who are, as Mr. Jellett says, cranks on ventilation. I call them cranks on cold air. They seem to think that air which passes through a ventilating system is not fresh air, that the only fresh air is the cold air from outside. I do not quite understand their idea, but they appear to think that the air which passes through a ventilating system, in some way or other, goes through the furnace and the chimney, and, perhaps, through the boiler, and then into the building. The fact is, physicians do not agree as to what is impure air. All of the experiments which have been made to determine the effect of impure air have been made by physicians, and the physicians do not agree. Some of them say that the only bad effect is due to the presence of carbon dioxide, that it displaces a certain amount of oxygen, and thereby produces a certain bad effect which they cannot explain. Now, if this be so, then the system which was described a minute ago might be better than one of the best systems. That was the system where the air supply was taken from the closets and urinals. I have tested the air in a urinal and found it contained less carbon dioxide than the air in

a schoolroom occupied by the pupils above. In other words, if the carbon dioxide be the sole test, then the air in the urinal was better than the air in the schoolroom. Upon what the physician thinks is pure air will depend largely the way in which he will want his apparatus run, without regard to what the contractor or the ventilating engineer says. If he thinks that the contaminations do not make much difference, why, he will shut off the ventilating apparatus. If he is a cold-air crank, he will shut off the ventilating apparatus and reduce the temperature. There is no way to overcome this, except simply for us to insist that we should have plenty of fresh air, a large amount for patients in hospitals and for pupils in schools. Let the doctors disagree, but let us follow that school which says that the air contaminated by a human being is unfit for breathing by other human beings. We have had here a number of horrid examples. I would like very much to have presented to us a good example. In the horrid example mentioned by Mr. Barwick, I notice that the vents are ten feet above the floor. In the horrid example mentioned by Mr. Cary, the vents are at the floor. Which is the more horrid, the one with the vents ten feet above the floor, or the one with the vents at the floor?

Mr. Barwick: It depends on how you look at it. I have a little book which was sent to me by the Robert Boyle & Sons' Company, of London, and they are cranks on natural ventilation; they damn everything else but that particular thing. They give a few colored pictures illustrating the different ideas of ventilation. Their method is direct aspiration from the centre of the ceiling, allowing the cold air to be passed in around the room at a height six feet above the floor, the heating to be done by direct radiation. When this plan is used you feel the sensible heat from the radiators; when the room becomes warm the cold air is admitted at the breathing line, and you breathe nothing but fresh, cold air, and the foul air goes up through the flue. The pictures are very interesting, and if any of you gentlemen would like to look at them, I will hand the book around.

There is a little thing in this book which comes very close to what you have said in reference to opening the windows, as follows: "I am aware that some medical practitioners do recommend hospitals to be ventilated only by open windows on both sides of large wards, even in winter in this climate (England),

and maintain that there is neither risk nor discomfort in doing so. They do not themselves, however, submit to such ventilation; that is, they do not themselves sit in their study or have their family to sit in the morning room or sleep in bedrooms with windows to the east open all the winter through. It is only bounce for matrons and nurses to acquiesce in such an arrangement and uphold it; they are themselves not confined to beds underneath open windows, but are moving about, in and out of the wards. Nor do they submit to that in their own rooms during cold easterly windy days and nights. The helpless patients scarcely dare complain or even admit that they feel a draught, if the nurse says they do not."—(Dr. John Hayward.)

Professor Kinealy: I want to have both sides of the subject discussed. I do not know which is right. Mr. Barwick says that the air from the breath goes up. How about the contamination from the body? If the contamination from the body also rises, then you continue to breathe that, whereas, if all the air goes down, you will continue to breathe fresh air from above. Which is right? There are two schools. I would like to hear from Mr. Jellett on this subject.

Mr. Jellett: It is a pretty difficult question, Mr. President. It depends in my judgment very largely on the shape of the room and the arrangement of the flues, more than anything else. I have made many examinations of rooms; one I described I think some two years ago.* The ceiling of that room was fifty feet high; the room seats six hundred men; it is the operating amphitheatre of a hospital, and the largest, I believe, in this country. The entire ventilation is from the ceiling. The air comes into the room at the floor, the building being built with a series of tiered seats around the operating pit. That is, an oval —the tiers of seats form an oval. The room accommodates, as I have said, about six hundred men. The air is brought in in cast-iron goose-necks under the seats, and is distributed by branches, which throws the air down against the plating of the floor, the floor being built of steel plates. There are 135 air openings into that room; the air is brought in at an average velocity of about, if I recollect rightly, 140 to 150 feet. The air is thrown at an angle. There is no perceptible draught. Sitting over it you do not notice it at all. The ventilation is by a series of large regis-

* Transactions, vol. iv. p. 227; vol. v. 69, 139.

ters in the ceiling. They average about three feet square. I made a series of tests during an operation in that room with a thermometer close to the floor—within one foot of the floor, and then afterwards at the ceiling. I wanted to test first the effect of temperature by this arrangement, because in an attic I had some very large aspirating coils supplied with high-pressure steam, to pull on these ceiling registers. Before the lecture began, when the room was empty, I took a reading of the thermometers every five minutes at these different points, and had the thermometers compared. The variation in temperature was one and one-half degrees between one thermometer at the floor and one located close to the ceiling; this was due to the great diffusion of the incoming air and by the location of the outgoing registers. There was an exceedingly large volume of air brought into the room in proportion to the number of occupants and in proportion to the cubic feet of space contained in it, so that the velocity was slow. The temperature of the incoming air was not excessive, I think about 110 or 112, somewhere in that neighborhood, and it is practically out of the question to get better ventilation than you get in that room. I have seen other rooms in which an attempt to do that same thing would meet with miserable failure. My own experience is, that you have got to consider the actual conditions existing in the room you are going to plan and use your judgment. In a great many of the hospital wards I have taken small registers with low velocity and put them under the patients' beds, raising them three or four inches above the floor to prevent dirt getting into them. But if you carry high velocity, that is a dangerous experiment. When you do a thing like that, you want to put a controller or something of that kind on your fan, because a very high velocity would be very disagreeable.

I have a recollection of a hospital ward where the entire outgoing ventilation is through a central aspirating chimney, which comes down through and has four open fireplaces. They keep wood fires burning there during the winter, in the first place for ventilation, and in the second place, to make the rooms cheerful for the patients. The air is brought in through the outer walls at a distance ten feet above the floor, the ceilings being fifteen feet. I never heard any complaint of draughts in those rooms. Of course, if you went close to the fireplace you would probably

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feel it, but in the occupied portions of the rooms it is not perceptible.

I do not think you can make a hard and fast rule that there is only one way to ventilate a room. I have always made it a practice to study the arrangement of a room, the position of the flues, and the velocity at which I was compelled to bring the air in and take it out, because sometimes you are forced to take in the air at a higher velocity than you want to, on account of the limited space you have to work in.

If there is some one here who thinks there is only one way to ventilate, I would like to hear from him.

LXXI.

DANGEROUS AIR DUCTS.

BY JOHN GORMLY,

(Member of the Society.)

The writer has noticed many things which appeal strongly in protest against a present custom, which if not contrary to legal enactment should speedily be so classed.

In such cities as New York it is not uncommon to see the intake shaft of a ventilating apparatus within the danger zone of the fresh-air inlet to a drainage system. Yet the "fresh-air inlet," so called, is frequently an outlet for drainage air. In fact, it is usually the principal outlet for such drainage air as may be between the curb trap, as established by law, and the end of a soil-pipe branch, we will say, on the tenth floor of a modern building.

It is a well-known fact that all modern closets are arranged to discharge from eight to ten gallons of water as speedily as a four-inch discharge pipe will permit.

Each closet discharge forms a piston of water weighing about one hundred pounds, falling vertically, on an average, probably one hundred feet. It will not overstate the case to assume six closets to a floor; or sixty closets to a ten-story building. With the frequent use of such closets there will be almost a constant discharge of air outward at the so-called air inlet of the drain, making such a locality a dangerous one for the air intake of a ventilating apparatus.

No ventilating engineer would voluntarily choose such a location for his intake shaft; yet many are so located, probably because the owner of a building will not give good paying floor space to an air shaft. The architect objects to locating such a shaft on the outside of a building from artistic motives, and the engineer is thus coerced into doing something he knows to be wrong and dangerous.

It is also true that if air were taken from a point above the

roof it would, in many instances, be no better than that taken from the curb line.

The ends of soil-pipe stacks above the roofs are a source of contamination to the upper air, as are also exhaust air shafts and smoke flues, particularly where buildings are erected so closely together, as is now the practice in all modern cities.

The time would appear ripe for our organization to advocate the filtration and disinfection of all air used through such ventilating apparatus as we are called upon to design.

The writer was required a short time ago to report upon the heating and ventilating apparatus used in schools. In that tour of duty he frequently noticed wrapping paper, rags, twine, hair, dust, and other foreign matter in considerable quantities, lodged in the wire screens of air-intake shafts of the schools. These could readily have been contaminated with disease germs before entering the air shafts. Think of the possibility for mischief had a smallpox or bubo-infected rag, twine, or hair been thus drawn into the intake shaft of a school or other building. To any one familiar with the germ theory of the propagation of disease such a state of affairs is startling.

In a building which the writer recently inspected, evaporating pans were located in the hot-air ducts, with a view to moistening the air of the building; also, probably, with a view to preventing dust from entering with the heated air. These pans were supplied with water through a stop cock, and had an overflow-pipe connection to the drainage of the building. On the overflow pipe a water-seal trap was placed, close to the pan, inside the hot-air duct. This location was chosen for the trap that it might not freeze; also, perhaps, to comply with the plumbing law which reads, " All fixtures shall be trapped close to the fixture." As an anti-freezing device it was a success, because the hot blast quickly evaporated all the water out of the trap and nothing was left to freeze. But a direct connection was established by the evaporation of the water from the trap, so that the air of the drainage pipes had free access to the hot-air duct and thence to the entire building. The foregoing remarks apply particularly to fan systems of heating.

Many buildings of moderate size are supplied with air through gravity systems of heating, by hot-air furnace, indirect steam, or water circulation. Frequently in such plants the air ducts

are constructed of bricks or tiles and are located beneath the basement floor.

In this form of duct, if sufficient care be not exercised to make the duct gas and air tight, a danger arises that injurious gas from decomposing matter may find access to the interior of such ducts and thence be disseminated throughout the entire building.

In the construction of such ducts the greatest care is necessary, because the bricks of which they are usually formed will permit gas and air to filter through, even though the joints be laid in a good quality of hydraulic cement. The infiltration is assisted by the partial vacuum in such ducts when in use.

The writer knows many blocks of dwellings supplied with air through very poorly constructed ducts, upon land which, for many years, was a burying ground for human beings. The soil under these houses may reasonably be supposed to be reeking with disease germs.

As thousands of lives are risked daily by just such unsanitary appliances, it becomes a duty to see that no one suffers by our neglect and carelessness.

Thousands of houses are erected on land graded on swamps with the offscourings and refuse of our large cities. A careful analysis of the soil underlying such houses would doubtless yield the microbe of almost every known disease. An air duct under ground in such a location should be absolutely air tight and so constructed that it would remain air tight for ages.

The ventilating engineer must look with suspicion upon drainage pipes traversing his ducts or in proximity thereto. The writer, in two recent cases, found sewage in the air ducts of dwellings, because of defective drains in proximity to the ducts.

A very unexpected source of contamination in hot-air furnace pipes taking air direct from the basement of a dwelling, without underground ducts, recently came to the attention of the writer, who was called to investigate why a hot-air register, which ordinarily gave a copious blast of heated air, should at once refuse to act when a case of scarlet fever developed in the apartment in which it was located.

An investigation disclosed the fact that the register was passing great volumes of vitiated air from the sick room and discharging it into the hot-air chamber of the heater, some twenty feet below, whence it was carried to the other rooms of the house.

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The reason for this erratic conduct on the part of the heater was the closing of all cellar windows in the night during a sudden cold spell of weather. The heater was constructed to take its air from the cellar, and when that source of supply was closed, it was choking for air, and took it from the next convenient point, to scatter disease with it in all the rooms of the house.

The lesson from this incident would appear to be that the cold-air supply to a heating apparatus should be so constructed that the closing of cellar windows would not affect it—that all heaters should obtain their air from out of doors, with no means of closing the supply.

In view of the many dangerous contrivances one will see, even in our best cities, for the supply of such a vital necessity as the air we breathe, can our association devote itself to a more important service for its members or the general public than the advocacy of legal enactments toward establishing a yearly inspection of all air supplies and heating appliances? A board of sanitary experts, who are also heating engineers, should approve all proposed systems of heating and ventilation before a permit is given for their installation. They should also inspect, yearly, every heating appliance already installed and should have the power conferred upon them to enforce obedience to reasonable sanitary laws, which it is our duty to formulate and to urge.

DISCUSSION.

Mr. Barwick: Some time ago I was called in by one of the members of the Board of Education of a city near this city, to look over one of their schools. This school had formerly been heated with furnaces. I went carefully over it, and when I came to the infant class, I said to the teacher, "This room is not fit to have any children in; everybody ought to be dismissed." I said the same thing to a member of the Board. I walked outside the door and I found its cold-air connection had been taken from beneath the extension under the water closet.

Professor Kinealy: Mr. President, this remark as to the air from the sewer reminds me of something in connection with what I said a few minutes ago. I remember reading only a short time ago an article written by a physician, in which he shows—to his own satisfaction, at least—that there is nothing in sewer air

that is of injury to human beings. He goes at great length to demonstrate his position, and, as I say, he does it, to his own satisfaction. He belongs to the class of physicians which I think we ought not to follow.

Mr. Barwick: One of the worst underground ducts I ever went into, is one that was in a certain post-office in this city. The ventilating duct was put in there some years ago. I found it half full of water, muddy and dirty, and I do not believe they ever could use it. It was intended to ventilate that building at one time. I see there have been a good many fans put in there since. I also found another case, of Mr. Adams's laying out. I put a cleansing screen in one of the post-offices. It was put in nicely, made all according to Mr. Adams's plans, and everything else was first-class, covered with cheese-cloth. I went there about a year afterward, and I found it all tattered and torn, black and filthy. I suppose it had never been cleaned.

Mr. Kenrick: Speaking of cold-air ducts, people are little aware of what passes through the cold-air ducts. Referring to the subject of cheese-cloth for screens, I know—for an actual fact—the experiment was tried in the city hospital in Boston, and the cheese-cloth became so filled up with dust and dirt that it had to be changed every twenty-four hours. That gives an idea of what passes through the cold-air ducts.

Mr. Barwick: I found a screen made of bolting cloth the other day—nice bronze-wire bolting cloth. We offered them a very nice screen, but they considered it too elaborate, so they had others erect one and reduced the area of it. Then they telephoned to know what was the matter with the fans. I went around and took a piece of cloth and wiped off the screen. You could not get any air through it before—it was all closed up.

Mr. Jellett: The cold-air duct is a source of trouble in many plants because it is one of the places that it is nobody's business to look after. The object of the screen is to catch the dirt, but it does not seem to follow to most people that after catching the dirt, you want to get rid of it. Everybody in the business has had that trouble, particularly with fan systems, where air is being drawn in by a fan. I recollect distinctly a very large college building near Philadelphia, where that system had been in use for three years. An ordinary macadamized country road ran along the dormitory building, in which the fan system was lo-

cated. It was dusty at certain seasons of the year, of course. I received a telephone message one day that they wanted me at once—that the heating system in the hall had failed. That was rather a startling message to receive. I reached a conclusion right away why it failed. I went up there, and as I was crossing the campus, the President met me, and he said, "We have discovered the source of trouble." I said, "You cleaned the cold-air screen, I suppose?" "How did you guess that?" he asked. "Because," I said, "I instructed the engineer so many times to clean it, and I found it dirty just as often as I instructed him, and I supposed that it was still being neglected." He said, "The dust on the screen was a quarter of an inch thick over the entire screen."

I have found in some places that they make those screens fixtures, and the intelligent janitor will come along with a dust brush and club the screen and knock the dirt into the flue. We might write a treatise on cold-air ducts and how to keep screens clean and distribute it all over the country, and I don't think you could get the average janitor to obey instructions. The difficulty is, they want a man for a few dollars a month and his board in such institutions. Brains are not a requirement; it is manual labor—put the coal on the fire and run the errands, and do the other things for so much money a month, and it is all right; it doesn't make much difference what he knows. While that condition exists, we must expect the troubles that we are having now. I found them in a private dwelling in Philadelphia some time ago, in a system I had put in five years ago, a system that had been very carefully gone into, because one of the members of the family was a man who was very sensitive to changes of temperature. He wanted a very even heating system and a large volume of air. I had a call to go there one day in the winter. They said to me, "We cannot understand what is the matter with the heating system." The first floor had always been excessively warm, because they wanted a temperature of seventy-five, but it had suddenly become cold. The temperature that day was not over sixty in that room, whereas the third floor was insufferably hot. I walked up to the hall register and held up my handkerchief, and it was at once drawn inwards. I said, "When did you take out the cold-air screen?" They said, "Why, the coachman has instructions to clean that twice a

week." "Do you know whether he has carried out his instructions?" "No, we do not." "Let us go down and see." The heating apparatus was drawing all its air supply from the first floor, carrying it down and then carrying it up to the second and third. We went to the basement and found the screen had half an inch thickness of dirt on it. It had been raining shortly before that, and the dust dried up quickly, and the screen held the moisture longer than some other places would, being in the position in which it was, between brick walls, away from the sunlight. It was not a macadamized street outside, but an asphalted street, where the dust is ground very fine and wind carries it, and it carried it into this duct and there it stuck fast to this screen. As soon as the screen was lifted out the heating apparatus did what it was intended to do, but until I took the screen out I could not convince those people that the screen had anything to do with it. Conditions at once changed. The first-floor radiators began to throw hot air in the rooms, which they had not been doing before. That was a case of intelligent people who were posted on matters of that kind, you would think, sufficiently to look into the matter. You will find the same thing in connection with several ventilating systems that are laid out. I have known some very fine systems to be simply ruined for want of a little thought and care.

I was asked a short time ago to examine the ventilation of a theatre. The proprietor wanted me to ventilate the upper gallery only. I told him I might as well try to ventilate a shelf in a closet without disturbing the rest of the closet. He said, "I bought a lot of registers, you see, and had them put in the ceiling at the back of the gallery." "Where do they discharge?" I asked. "Into the loft." "Where does the loft discharge?" "Oh, I don't know." I said, "Haven't you ever looked it up?" "No; I don't think I have ever been on the roof." I finally got to the roof through a ladder in the closet. I found that the large central ventilator, designed to carry this air out, had been carefully covered with paper and then boarded up. But he had bought all these registers and never thought of what happened to the air after it got into the loft. That was too much for him.

Mr. William Kent: I do not want to discuss the paper, but I do want the secretary to call upon the members of this society for a paper on the subject of screens, and how they should be

made for different purposes. There is a subject for a good paper and a good deal of discussion at some other meeting. This book of Robert Boyle & Sons' Company which has been placed in my hands here by Mr. Barwick is also a subject for another paper. I hope Mr. Barwick at the next meeting of the society will read a critique of this book. If it is wrong, we want to know it. These pictures ought to be reproduced in colors just as they are here, and if they are wrong the antidote ought to be printed with them. If they are right, it ought to be shown by tests. Here is a chance for anybody that wants to write a good paper.

The President: Gentlemen, in connection with cold-air supply ducts, my experience is that those underground should always be avoided if possible. Sometimes you cannot avoid them. You strike sewer pipes and everything else in connection with it, and occasionally you have to go through them. I want to relate to you an experience I had several years ago with a building which is now torn down. It was a United States building. The basement and first story were ventilated through cast-iron columns, and they connected with underground vent ducts, which were carried to the main shafts, of which there were four in the building. There were also fresh-air ducts under the floor which crossed under these vent ducts. They came from the outside of the building to the central hot-water chambers, indirect radiator chambers—the building was heated by hot water—and they crossed under these vent ducts. Through these vent ducts they had two ten-inch sewers at one point of the building. One day the sewer was stopped up, and some one in the building went to see this pipe. He cut into it and he found the sewer, and he cleared the sewer, but neglected to close it up; he left it open. In the meantime, somebody cut the connection between the vent ducts and the indirect radiators which were below the level of the vent ducts. As a result, when the sewer was flushed, when there was a great deal of water in the sewer from any stoppage outside in the street, the overflow of sewage went into the vent ducts, and from there into the cold-air supply ducts and into the indirect radiator chambers. In the building were two batteries of return tubular boilers, of eight boilers each. The floor of the boiler room was about four feet below the basement floor. The smoke went back over the top of the boilers, and the bridge was built over the back of the boiler direct from the main building

walls and formed a tunnel under the bridge from the back end of the boiler and the wall which was low down, and in that tunnel below there was, I think, an eighteen-inch hot-water main. That pit somehow was also connected through making changes with the vent ducts in the rest of the building, with the result that that always was full of sewage and covered the hot-water return pipe. It was not found out until the heating apparatus was started. Then this mass commenced to boil and went all through the building. That is one of my experiences which has led me to make up my mind that I never will use a cold-air duct under a basement floor if I can help it.

Mr. Hugh J. Barron: I hardly think refusing to use underground ducts gets over the question or helps the problem in the least. It is a problem that I guess we are striking every few days. Only a short time ago I took a contract for a fan system, and the first thing I found when I got to the building was an eight-inch drain pipe crossing the ducts at various points, and the drain pipes are in there to-day, regardless of my friend Gormly's criticism, and they will be in there as long as the building lasts, I presume, and the hot air is going over it. I do not see how you can avoid that in modern construction. The whole modern conditions are that way. Ground is valuable, and the spaces are insufficient to accommodate everything. The consequence is that you have to do the best you can. You have to use your ingenuity to get over the difficulty the best way you can. We do not get over it by saying it should not be done. That does not help us in the least.

The President: I understand that perfectly well; what I mean is, that it is to be avoided as much as possible. The very moment that somebody goes and cuts into that sewer pipe we have trouble.

Is there any further discussion on this subject?

Secretary Mackay: Mr. President, on the subject of cold-air supply, I happened to run across a peculiar circumstance, which resulted disastrously for the party placing the apparatus and all connected with it. It was in the city of Scranton, Penn., a little over a year ago. I had nothing to do with the particular apparatus, but I happened to be calling on the party who was placing it. While I was there the building was in the rough. The fans and heaters had been placed. The sides of the cold-air ducts

were bricked up, ready for closing over. There had been a good deal of rain, and they were bothered with surface water. The ducts were standing about half full of water. The superintendent of the concern that was placing the apparatus suggested that they tap the drain to get rid of the water. The drain was at a lower level. They tapped the drain and got rid of the water. Some two months after that I learned that they were having trouble in the school—a number of cases of sickness—the school being finished and occupied meanwhile. They investigated the trouble and the Board of Health of the city made an examination. They found that the direct connection to the drain was still open, and they were pumping this sewer air from one of the highest points in Scranton. Of course, if there was any gas generated it would be at that point, and they were pumping that into the school. A suit was started against the man who cut into the drain and against the superintendent who ordered him to do it, and against the firm who placed it, one of the leading firms in that vicinity. How it was finally disposed of, I do not know, but I think that any of those three parties will never attempt to connect a sewer with a fresh-air duct in the future.

Mr. Barwick: I remember a little case where I was called in to ventilate a room in which I proposed to use two furnaces. It was the only thing adapted. After we got the furnaces set up and everything all ready to connect up with cold air, I told the man to tear up the cold-air duct and enlarge it, and make it big enough for the two furnaces. He tore it up. He found the skeletons of two cats and I don't know how many rats. It was pretty well filled up. I asked, "Was there any screen there?" He stated there was none. He said they did not use a screen; that there was an iron grill above the areaway. I asked, "How did they get in there?" He answered, "I don't know." However, I put in a screen there. They had been complaining about foul smell. They couldn't find it. Nobody else could find it, until they took that duct out and changed it over.

LXXII.

METHODS OF TESTING BLOWING FANS.

BY R. C. CARPENTER.

(Member of the Society.)

The following paper is a supplement to the one presented to the Society at its last annual meeting, and is intended to call attention to certain difficulties experienced in the testing of blowers, with the expectation that the discussion will give valuble suggestion and possibly lead to the adoption of standard methods.

Object of Test.—The object of the test made on a blowing fan is, in nearly every case, the determination of the capacity of the fan either to move a given volume of air or to produce a certain pressure, or the determination of both of these qualities; also the determination of the power required for moving a given quantity of air under a certain pressure; and, finally, the efficiency of the fan. From complete tests as outlined above can be determined the economic value of different forms, and usually the costs of moving certain quantities of air under given conditions.

It is necessary, to meet these requirements, to make accurate measurements of, first, the power required to operate the fan; second, the volume and weight of air delivered by the fan; third, the pressure produced by the fan; fourth, the work performed and the efficiency.

Referring to these various requirements, it will be found that the measurement of the volume of air is the one most difficult to obtain with any degree of accuracy.

The measurement of the power required to operate the fan can generally be made with accuracy, although the method used will depend upon the character of the power. If the fan is driven by a steam engine, the total power can be obtained

from indicator diagrams with an error perhaps less than 2 per cent. The indicator shows, however, not the power applied to the fan, but the power applied to the piston of the engine, and this must be corrected by deducting the power consumed in engine friction. The latter may be obtained accurately from indicator diagrams taken when operating the engine and belt, without moving the fan, at various speeds. More accurate measurements of the power may be obtained by use of a transmission dynamometer which is directly connected to the fan, and which is driven by an engine and arranged so as to show the transmitted power. In the various tests on fans which have been described to the Society by the author in the past, both methods of measurement of power have been used, and comparisons have been made which show that the results are essentially the same by either method. In the tests which will be described in the following paper, the power was measured by an Emerson Power Scale which was mounted on the same axis as the fan. The mechanism as arranged in this way gave accurate and satisfactory results.

The volume and weight of air delivered by the fan is almost invariably obtained by measuring the velocity of the air, and from this computing the volume and weight. With the average velocity known, the volume is readily computed by multiplying the velocity by the area of cross section through which the air flows. The weight is computed by multiplying the volume or number of cubic feet by the weight per cubic foot, which is to be obtained from tables prepared for such uses.* The measurements of velocity of the air are usually made with the anemometer or the Pitot tube.

The anemometer was probably first used by Woltmann or Kallsténius as early as 1820. It consists of a very delicately constructed vane wheel, so mounted as to be revolved by the air. A counter and graduated scale gives the velocity of the air striking the vanes usually in feet per minute. The anemometer is provided with detent motion, so that the register can be stopped or started at the will of the operator. A form of the anemometer designed by M. Morin, as shown by Péclet in his work on "Heating and Ventilation," is shown in Fig. 1 as used about 1840; this form is interesting as showing that but little

* See appendix work on "Heating and Ventilating."

improvement has been made in this instrument during the last generation.

It was shown by M. Combes in 1838 that if n be the number of turns of the vane wheel of the anemometer, and a and b constants, that the velocity of the air would be expressed by a formula

$$v = a + bn;$$

this would signify that a constant to be determined by experiment must be added to the anemometer readings. Such con-

FIG. 1.

stants are usually given with every instrument by the makers, and are supposed to be determined by calibration.

The anemometer is a delicate instrument, and its continued use is liable to increase the friction of its working parts and cause variation in the constants a and b; for this reason it should be calibrated from time to time. The method usually prescribed for calibrating an anemometer is to fix it to a revolving arm of considerable length and swing it through still air a known number of revolutions corresponding to a certain distance of travel. The error of the instrument is determined by comparing the reading of the instrument with the distance passed through by the anemometer. Another method of calibration is by comparing the reading of the anemometer with air moving at a known velocity. The velocity of air moving through a duct of a given cross section can be computed by measuring the amount of heat required to warm the air through a certain number of degrees. This may be done as illustrated in the diagram Fig. 2. A duct A, B, C, D, is supplied with air by means of a blower located in some convenient position. A

heater is placed in one end of this duct as at B, the anemometer to be tested is placed beyond the heater at some point N and arranged so that successive readings may be taken at all portions of the cross section; the stopping and starting mechanism is arranged so as to be operated from the outside of the box. One or more thermometers are located at T T′, thus permitting the measurement of the difference in temperature of the air. Dry steam is supplied the heater at F, and the water of condensation is drawn off at E, being maintained at a constant level by aid of the gauge-glass g. Every pound of steam at known pressure and quality contains an amount of heat which is accurately obtained from the steam table, so that means are provided for computing the heat units given off. As this must all have been

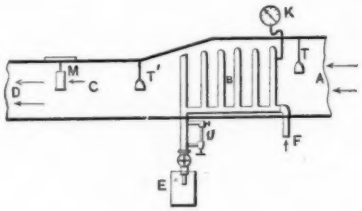


FIG. 2.

used in warming the air through a temperature T′—T, we have means of computing the weight of air: as the specific heat of air is 0.238, one heat unit would warm as many pounds of air one degree as 0.238 is contained in unity.

Let H equal the total number of heat units given off by the steam, R the radiation or loss of heat units between the position of the thermometers—this is usually very small, but can in any case be determined by cooling experiments—T and T′ the temperatures before and after passing the heater, W the total weight of air in pounds, Q the total volume of air in cubic feet, A the total cross section of the duct in square feet at the position of the anemometer, and C the number of cubic feet of air per pound for the given pressure as determined by tables. For the reasons already stated we have

$$W = \frac{H - R}{.238\,(T' - T)}$$

$$Q = C \times W;$$

from this we have the velocity

$$v = \frac{Q}{A} = \frac{CW}{A} = \frac{C \quad (H - R)}{A\, 0.238\, (T' - T)}.$$

By comparing the velocity of the air as computed in this manner with the average reading of the anemometer, the error may be determined.

The errors of anemometers can also be obtained by direct comparison with instruments having known errors.

The velocity of air flowing through a duct of given size may also be determined by the use of large measuring tanks which are alternately filled and discharged with air in such a manner as to give accurately the volume of air flowing. We have recently arranged in Sibley College two large tanks, each holding

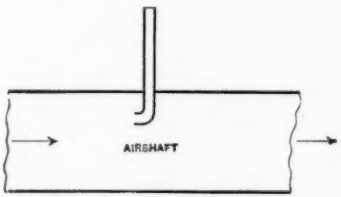


FIG. 3.

about 300 cubic feet, for the purpose of accurately measuring the volume of air discharged. Up to the present time this plan has not been used to calibrate anemometers, although it is capable of such use.

The Pitot Tube.—The Pitot tube for measuring air velocity is made by connecting a delicate manometer to a tube bent in such a manner that the opening can be made to face the current of flowing air. By comparing the readings of a manometer connected in this manner with a manometer connected so that the mouthpiece is at right angles to the current of flowing air, a difference in readings will be noticed, which is caused by the velocity of the flowing current. The reading of the Pitot tube in excess of the static pressure is produced by the velocity of air, and is proportional to h in the formula

$$v = k\sqrt{gh},$$

in which v is the velocity of the air in feet per second, and h is the head which is counterbalanced by the force causing the velocity, and may be measured in various units as inches of water, ounces of pressure, feet of water, etc.

If measured in inches of water, which is probably the most convenient measure, the theoretical value when $k = 1$ becomes

$$v = 46.8\sqrt{h}.$$

A series of experiments gave as a practical result

$$v = 70\sqrt{h},$$

corresponding to a value of $k = 1.47$*; when air is at a temperature of 120 degrees, $v = 66.7\sqrt{h}$, corresponding to a value of $k = \sqrt{2}$ when air is at a temperature of 60 degrees Fahr. For air at other temperatures this result must be multiplied by the following factors:

Temp. Air. Deg. F.	Factor.	Temp. Air. Deg. F.	Factor.
32	0.92	100	0.985
60	0.95	120	1.00
80	0.965	150	1.05

By connecting one side of the manometer to a Pitot tube and the other side to a plain tube the manometer may be made to show the difference of pressure due to the velocity of the air by a single reading and without subtraction. A form of Pitot tube, with a very delicate reading manometer, as supplied by Schaffer & Budenberg, of Brooklyn, N. Y., and as designed by the writer, is shown in Fig. 4 in position in a pipe.

The diagram Fig. 5 represents a graphical method of obtaining, without labor, the velocity of air from readings of the Pitot tube. The diagram, as arranged, has readings of Pitot tube horizontally at the bottom, while corresponding velocity results are to be read on four scales located two on each side. For instance, if the manometer reading is between 1 and 10 inches, the readings will be taken opposite the lower diagonal line on the left-hand scale; thus, if the Pitot tube reading is 2.5 inches,

* It should be noted that h is greater in relation to v as the value of k is less.

we note the intersection above 2.5 with the first diagonal line, the velocity read on the left scale is, by interpolation, 108. If, on the other hand, the reading of the manometer is 2.5 tenths or 0.25 inch, the velocity would be read opposite the upper diagonal line on the right-hand scale, and would correspond to 35.7 feet per second. If the manometer reads 2.5 hundredths of one inch, the velocity would be found by noting the intersection of the vertical through 2.5, with the lower diagonal using the scale on the right, which gives us, by interpolation, 10.8 feet per second. If, on the other hand, the reading was 2.5 thousandths, the velocity would be found by noting the intersection above 2.5

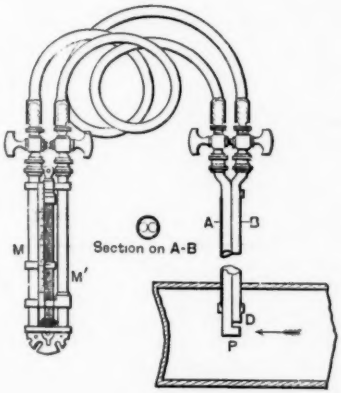


FIG. 4.

with the upper diagonal, the velocity being given by the scale at the left as 3.57 feet per second. In practice it will be found that quite accurate measurements of the velocity may be obtained for the higher manometer readings, but that considerable percentage error will be likely to result in obtaining the velocity from the low manometer readings, due principally to the difficulty of making accurate readings of low manometer values. The Pitot tube is, consequently, well adapted for measuring high velocities of air and, with a sufficiently delicate manometer, it will give good results in measuring moderately low velocities.

It is not, however, as well adapted for low velocities as the anemometer, nor can it be used as conveniently.

It will be noted that the Pitot tube will give the velocity at a

position of limited area, and hence with this instrument it is possible to obtain the velocity at any given point in the cross section of a flue and at some distance from the manometer.

The writer has tried in connection with the Pitot tube several forms of multiplying manometers, but has not obtained as satisfactory a result as with a close reading direct manometer which is provided with a micrometer for giving the decimal portions of an

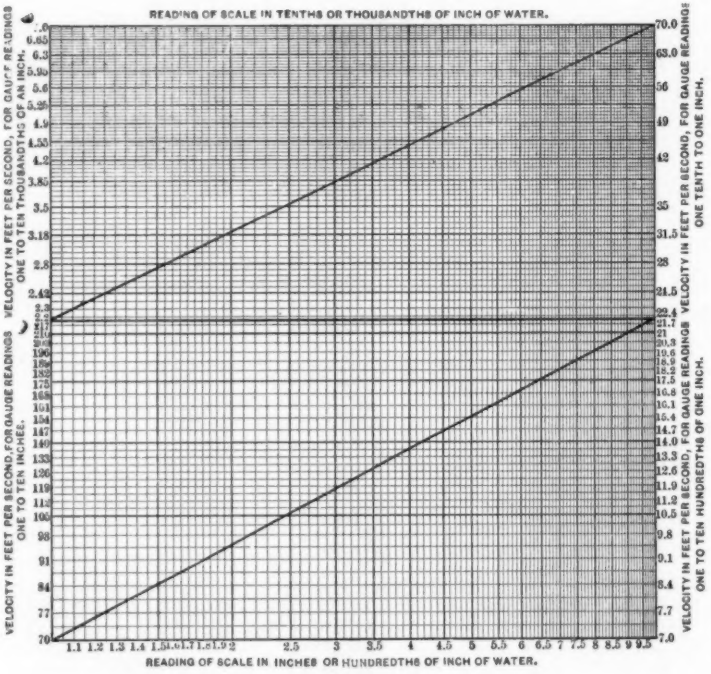

READING OF SCALE IN TENTHS OR THOUSANDTHS OF INCH OF WATER.
VELOCITY IN FEET PER SECOND, FOR GAUGE READINGS ONE TO TEN INCHES.
VELOCITY IN FEET PER SECOND, FOR GAUGE READINGS ONE TO TEN THOUSANDTHS OF AN INCH.
VELOCITY IN FEET PER SECOND, FOR GAUGE READINGS ONE TO TEN TENTHS OF ONE INCH.
VELOCITY IN FEET PER SECOND, FOR GAUGE READINGS ONE TO TEN HUNDREDTHS OF ONE INCH.
1.1 1.2 1.3 1.4 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5
READING OF SCALE IN INCHES OR HUNDREDTHS OF INCH OF WATER.

FIG. 5.

inch. In most of the multiplying manometers the vibration of the water column effects the reading to such an extent as to counterbalance the advantages due to the system of multiplication employed. Several forms of manometers are described in the description of apparatus used for measuring pressure which follows.

In 1884, the Prussian Mining Commission investigated, by means of a large gas-holder which contained over 70,000 cubic

feet, the following questions relating to the measurement of the velocity of air:

(1) Do the formulæ generally used for standardizing anemometers in a circular path in still air give correct results or not?

(2) Can the Pitot tube be applied practically for measuring the speeds of air, and, if so, what formula should be used for calculating the speed and quantity of air?

(3) May the fall in pressure between one side and the other of a thin orifice interposed in a pipe, be used to determine its velocity, and, if so, what formula should be applied?

(4) What is the loss of head due to friction caused by the length and diameter of pipe used?

(1) The results of this inquiry were briefly as follows: first, that anemometers calibrated by swinging in still air show errors which range between 7 and 13 per cent., the anemometers always reading high.

(2) A Pitot tube may be used with accuracy for measuring the velocity of air, the formula being as follows: velocity of air in meters per second at zero centigrade

$$= 4.265\sqrt{\frac{\text{pressure in mm. head of water.}}{\text{density of air}}}$$

This reduced to the average temperature and density of the air becomes $4\sqrt{h}$, h being the head in millimetres of water.

(3) The fall in pressure between one side and the other of a thin orifice may be used. If H is the difference in pressure represented by feet of air, the formula for flow would be

$$Q = CA\sqrt{gH},$$

in which A is the area and C a coefficient which equals 0.64 for circular orifices and 0.61 for square orifices.

(4) The loss in head due to friction as obtained in a cast-iron pipe 14.3 inches in diameter, was found to vary as the diameter of the pipe affected with the exponent 1.32, as the square of the velocity and as the density affected with the exponent $\frac{2}{3}$.

The general results of the tests show that the anemometer gives an exaggerated value of the air discharged by a fan, especially when standardized by rotating in still air. In computing

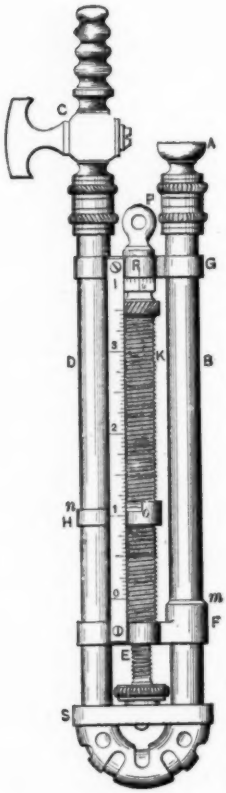


FIG. 6.

DESCRIPTION.

The accompanying cut is half size. The form of the Draught Gauge is U shaped and consists of the following parts: The U glass tube *B D*, air cock *C* for hose connection, cup *A*, guides *G* and *F*, vertical scale *I* which is divided into inch, half, quarter and one-twentieth of an inch, screw *K* for adjusting index pointer *O*, and having twenty threads to the inch; the index wheel is divided into twenty-five parts, and the whole combination is raised and lowered by screw *E*; *S* serves as a protection for glass tube and bearing for *E*.

Since the screw *K* has twenty threads to an inch, and the scale is divided into $\frac{1}{20}$ of one inch, then for one turn of *K* it moves index *O* one division, and since the index wheel has twenty-five divisions, each division is then equal to $\frac{1}{25}$ of $\frac{1}{20} = \frac{1}{500} = .002$. For example, if second division to the right of zero on the index wheel were placed on *R*, it would then be read $1 + \frac{1}{20} + \frac{4}{100} \times 2 = 1 + 0.1 + .004 = 1.104$; *i. e.* each small division on scale *I* is equal to .05, and on index wheel equal to .002.

The instrument is nickel plated and enclosed in a handsome morocco case.

METHOD OF OPERATION.

The glass tube is filled with water to about one-third its height, one end of a flexible rubber tube is then connected to cock *C*, and the other end is inserted into the chimney flue. *B* is then open to the atmosphere and *D* is in communication with chimney flue. There will now be a difference of water level in tubes *B D*. Adjust *m* so that it will be tangent to bottom of meniscus by screw *E*, and *n* by means of screw *K*. If it is desirable, cock *C* can be closed and the difference of water level maintained and taken to some convenient place to read.

the volume of air delivered, the error in the result would be directly proportional to the error of the anemometer, which, as shown by the previous tests, averages not far from 10 per cent. high. The error in work performed and in efficiency, however, would vary as the cube of velocity and, consequently, as the cube of the error in the anemometer. If the anemometer error be 10 per cent., the error in work done and in efficiency would be 33 per cent.

Measurements of Pressure.—The difference in pressure pro-

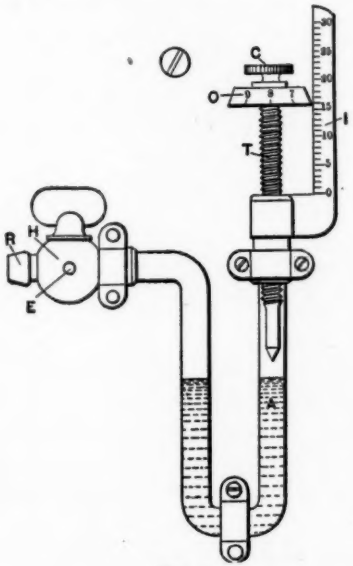


FIG. 7.

duced by a blowing fan is usually very small as compared with the total barometric pressure, and is ordinarily measured by some delicate gauge. The simplest apparatus and the one most commonly used is a U-shaped tube filled with some liquid such as water. One side of this tube is put in connection with the vessel subjected to the pressure to be measured; the other is connected with the atmosphere, or, as explained in the discussion on the Pitot tube, in such a manner that the difference of any two pressures may be read directly.

The delicacy of the instrument will depend upon the weight

of the liquid used; the heavier the liquid the less delicate is the instrument.

For the measurement of air pressures, water is ordinarily employed, and the results obtained are expressed directly in inches of water or are reduced to ounces or pounds per square inch. By locating the U-shaped manometer in such a position that the eye can sight over the under surface of the liquid in the tube, a very delicate reading may be determined by aid of the total reflection of light as seen from the meniscus at the top of the column of liquid. An elevation considerably less than one-hundredth of an inch can thus be determined with accuracy. By arranging a point back of the last tube and one in front and noting the position of the bottom of the meniscus, very delicate changes can be read. The writer has designed a direct reading

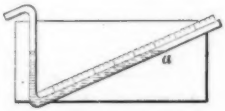


FIG. 8.

manometer of this type which is manufactured by Schaffer & Budenberg, which is arranged to read to thousandths of an inch by means of an attached scale and micrometer screw. The zero of the instrument is adjustable so that a single reading gives the difference of level. The form of this instrument is shown in Fig. 6.

Another form of direct reading manometer, as designed by Professor Kinealy, is shown in Fig. 7, in which the level of the water is shown by contact of a sharp-pointed screw; the level of the surface being determined by the readings of a manometer screw on an attached scale, two readings being necessary to determine the difference of level.

Several forms of indirect gauges, by means of which the readings are multiplied, have been designed. One of the simplest forms consists in the use of an inclined tube for one of the legs of the U-shaped manometer. This arrangement permits the use of a longer scale, which is subdivided in such a manner as to give small fractions of an inch, and is shown in Fig. 8.

Another form consists in the use of a U-shaped tube con-

necting with the large bulbs at each end (Fig. 9), in which two liquids of different color and of slightly different density are used. The line of junction (a) of the two liquids being in a small tube, will move a much greater distance than the surface of either, and this is utilized for multiplying the readings. This is an excellent gauge, but the value of the readings should be determined by trial. Kerosene and colored water make good liquids for use.

A modification of this gauge, as designed by J. C. Hoadley,

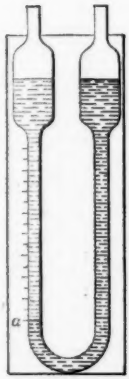


FIG. 9.

was described in Vol. II., Transactions, and is represented in Fig. 10.

Mr. Kent described before the Society in Vol. III., Transactions, a very excellent form of multiplying draft-gauge, which is shown in Fig. 11; this we have used with success. A pipe leading to the pressure to be measured is connected under the vessel A, which is suspended by a delicate spring over the vessel B, which is partly full of water. The amount of motion for a given difference of pressure is dependent upon the strength of the spring and the area of the top of the vessel A, and its value should be determined by calibration; it can then be subdivided as desired.

A form of multiplying manometer, shown in Peclet's "Traité de la Chaleur," is represented in Fig. 12. It consists of an air-tight box partly filled with water, the upper portion of which

is connected with the chimney or vessel under pressure. The pressure is measured by a float connected to a revolving axis on which a pointer is attached; the float, moving in a well which is subjected to atmospheric pressure from above, will change its position dependent upon the pressure in the chamber A.

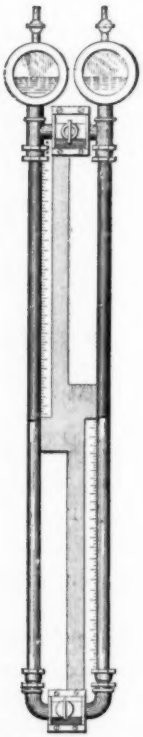


FIG. 10.

The graduated scale serves to show the draft. The instrument is to be calibrated by an attached manometer M. This instrument might be a very valuable one for use under conditions where it would not need to be moved. Its form is not well adapted for moving around.

Peclet shows several forms of manometers in his work, many of which have been reinvented since his time and now pose as

novel constructions. The ones of principal value are those which have been described.

The Work of the Fan.—The work performed by the fan is made up of the resistance due to moving and compressing a definite amount of air. It can all be considered as equivalent to moving a given weight of air through a height or head which is equivalent to the sum of the velocity and pressure heads ex-

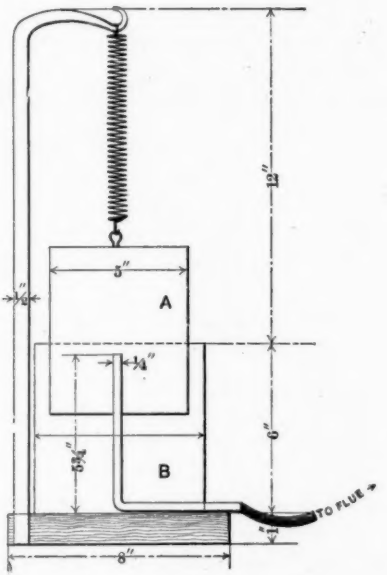


FIG. 11.

pressed in feet of air at the density corresponding to the air after being compressed. These results can be expressed in the shape of a formula. Thus let Q equal the volume of the air at atmospheric pressure, Q′ its volume at delivery pressure, c′ the weight per cubic foot at atmospheric pressure, c′ the weight at delivery pressure, W′ weight of air delivered per second, d density at atmospheric pressure, and d′ at the delivery pressure, v the velocity, A area of cross section at point of measurement of velocity, and M work in foot pounds per second; then we shall have —

$$Q = vA = Q\frac{dv}{d'}A,$$

$$W = Q'c' = Q\frac{d}{d'}c\frac{d'}{d} = Qc,$$

$$M = \text{work} = Wh' = Wh\frac{d}{d'} = Qch\frac{d}{d'};$$

in which h equals the sum of pressure head and velocity head as measured at the same point expressed in feet of air at atmospheric pressure, and h′ the same quantity expressed in feet of air at delivery pressure.

In the testing of the fan it will be found that the pressure head,

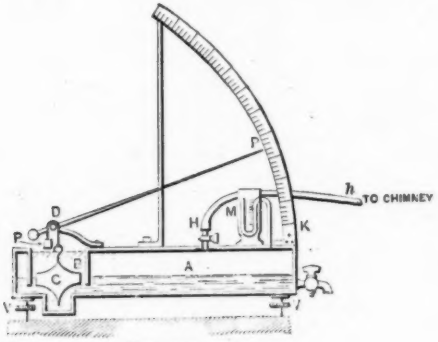


FIG. 12.

as measured from the manometer, will be smallest, as a usual thing, when the velocity head, as measured from a Pitot tube, is highest, and vice versa. Hence it is essential to measure these two quantities at the same point.

In case the velocity head cannot be directly measured by use of a Pitot tube, but instead of that the velocity is measured, the corresponding velocity head may be computed from the formula

$$h = \frac{V^2}{2g},$$

which is quite accurate for air of 60 degrees temperature, but would be subject to correction for other temperatures, which may be deduced from the table previously given.

Efficiency.—The efficiency of a fan is to be found by dividing the work supplied by that usefully applied in moving the air, and computed as explained.

Notes Regarding Testing of Fans.—It will be found in the actual operation of testing fans that the air delivered moves in irregular currents, and, consequently, in order to obtain average results, readings must be taken in all portions of a given cross section. In order to obtain the average readings, the cross section should be subdivided into a number of small sections of equal area, and the velocity in each one of these smaller subdivisions should be obtained by the method described.

In case the subdivisions are not of equal area, an allowance should be made in determining the average for those subdivisions which are larger, by multiplying the readings by factors giving the relative proportion of area.

As a rule, the pressure and velocity readings of the fan should only be taken after the air has travelled some distance, in order that the inequalities spoken of may be lessened as much as possible.

The use of baffle-plates to equalize the velocities and pressures is likely to add considerable friction head to the fan, and they are not recommended.

Many of the tests which have been recorded of fans show an abnormal and sometimes an impossible efficiency. This is usually due to errors in the anemometer used, which make practically about three times as much difference in the efficiency as in the volume of air delivered, due to the fact that the error in volume would vary as the error of the anemometer, whereas the error in efficiency and in work performed would vary as the cube of this error.

There are certain losses which necessarily take place in the fan when constructed in the most perfect form, which are due to the striking of the particles of air against the vanes, to adverse air currents at the point of discharge from the vanes, and to friction against the casing. It is considered by some authorities that the unavoidable losses will reach from 25 to 33 per cent. of the power supplied the fan, and hence the limit of possible fan construction will result in an efficiency of from 66 to 75 per cent. The efficiency of a fan varies with the pressure against which it works, the highest efficiency being usually found in our

DEPARTMENT OF EXPERIMENTAL ENGINEERING,

SIBLEY COLLEGE, CORNELL UNIVERSITY.

TEST OF BLOWER.

Kind ..... Date .....

Form of Blades ..... Discharge Area.....

Diameter of Fan..... Temp. of Room .....

Width of Fan..... Barometer .....

Form of Inlet..... Anemometer Diam .....

Inlet Area ..... " Coefficient .....

Formula ..... Weight of Air per Cu. Ft... .....

Made by.....

No. of Run.	I.	II.	III.	IV.	V.	VI.
Time begun						
Time ended.....						
Length of run						
Duration in minutes						
Tachometer						
R. P. M. of Fan						
Air pressure per sq. in., ounces. Average.....						
Pressure head in water, inches. "						
Velocity " " " "						
Anemometer readings. "						
Velocity of air, feet per second. "						
Cubic feet discharged per second						
Weight of air discharged per second.....						
Velocity of fan blade tips, feet per second.....						
Dynamometer reading						
" horse-power						
Developed horse-power.....						
Cubic feet air per H.-P. per second						
Efficiency, per cent						
... .						
.....						
.....						
.....						

experiments when the fan is working under a back pressure of approximately one ounce. Working under the condition of highest efficiency, the fan discharges the greatest weight of air per horse-power, but not necessarily the greatest volume, unless the volume be measured at atmospheric pressure.

It will also be found that the form of the fan blades has considerable effect on the results. In my experiments with different forms of blades at a given speed, the highest pressures have resulted when the fan blades were bent forward and the highest efficiency when the fan blades were bent backward.

The general results of my experiments would indicate that a fan efficiency of from 40 to 50 per cent. is as high as can be expected with the best construction working under usual conditions, and, furthermore, that any published efficiency which is greater than 50 per cent. is to be regarded with considerable suspicion.

Form of Blank for Recording the Results of Blower Tests.—In connection with tests of blowers in Sibley College, Cornell University, we have arranged the form shown on the opposite page to tabulate the average results of the tests. The blank is presented for criticism and also in the hope that it may be useful for the purposes for which it was designed.

DISCUSSION.

Professor Carpenter: I should be very glad to have other suggestions. I might say that when I started out to write the paper, I intended to give results of tests that we have been making, and with fans having different forms of blades, but I found that I had so many references to the method of testing and the time was so limited that I finally confined the paper to this particular phase of the subject, hoping to bring up the other phases at a later opportunity.

Mr. J. J. Blackmore: I would like to ask Professor Carpenter a question, as to whether the blades of the different fans he tested were of the same distance from the edge of the blade to the casting of the fan, and what the difference was, whether there was greater or less space between the blade and the casting?

Professor Carpenter: I would say that we made a series of tests, perhaps thirty or forty, with a fan we specially constructed,

run in different casings, using a scroll of different dimensions and in different positions with respect to the fan wheel, and we found that the position of the scroll has a very great deal to do with the efficiency of the fan. In a general way, the scroll at the point of discharge should be at least one diameter's distance of the fan wheel from the outer rim of the wheel to give the best results, and at the nearest point I think it should not be less than one-third the diameter of the wheel; that is, the scroll should vary in distance from the wheel, from about one-third the diameter to full diameter of the wheel. As to the best position of the scroll, we found, if the scroll was close to the wheel, that not only was the fan inefficient, but it made a considerable amount of noise. Within the last few weeks we had an accident —a very peculiar one—and considering the place where it occurred, it was quite laughable. It illustrates, however, this particular point. One of our buildings has lately been heated by an improved system of blower heating. The fan ran without attracting notice for three months. Everything was supposed to be all right until a cold snap came along about the holiday time; then the people in that building could not get warm. One of the professors examined into the question and could not see that there was any cause for the trouble. The fan was electric-driven and about twenty-two amperes of current was required to run the fan. I was sent for, and, on examination, found that the fan had been running backwards for three months past. It had been driving air into the building through a small hole which is perhaps about a foot wide. We reversed the motor immediately, and then took the readings of the current required, and, very much to my surprise, not only was there an increase in the air delivery, but the electric current required fell off. Whereas it took twenty-two amperes to run the fan going backwards, delivering very little air, it required but twelve amperes with the fan running the right way and delivering probably six or eight times as much air. This shows that the form of the scroll is of very great importance in respect to the efficiency and capacity of the fan.

Professor Kinealy: I would like to ask a question. What do you suppose, Professor Carpenter, the probable error of any one test? In other words, suppose that you have a dozen tests, what would be the difference between the one farthest below the

average and the one farthest above the average? What would be the difference in comparison between those tests and the average? What is the probable error of your measurements? We know that for every instrument there is always an error—a probable error. There is also an error due to the observer—the personal error of the observer. Now, what do you think is the probable error of one test in this series?

Professor Carpenter: Professor Kinealy can ask a very hard question. I think of all questions ever asked me, that is the hardest one to answer.

Professor Kinealy: It is easy to ask the question.

Professor Carpenter: I think Professor Kinealy is a very good school-master, and I am afraid he has got a very poor pupil in this particular instance. I think it is, perhaps, nearly impossible to answer that question in a general way. But I will tell you what I have been accustomed to do to get some idea of the magnitude of the error, that is, to plot out results in a curve. If we can know the theoretical law of the curve in advance of plotting, it is of very great advantage, but if the points fall in line or almost exactly in a line, we consider the error is small, proportional, perhaps, in some cases, to the distance from the line, and we use that curve very largely to determine the percentage of error. Now, what the probable percentage of error is in any given experiment, is difficult to state in advance of the test. We do not do work nearly as accurately as a good many imagine, even with instruments which read wonderfully fine. You will sometimes find that we do work with instruments which read to the very smallest fraction in some cases, and yet in other cases have, for equally important positions, instruments in which the relative readings are very coarse. In such cases the relative error in the result will depend on the poorest instrument. Then, of course, we all make errors of observation, and we make mistakes. Mistakes are things that can usually be detected by plotting the results. If an observation comes a long way from the curve, I throw it out as being a mistake, or at least do not give it much weight.

Professor Kinealy: What do you call a large error?

Professor Carpenter: It would depend graphically on the scale I employed. If the error were large the point would be some little distance, or so far away that we could not consider

it as belonging to the same class or in the same curve with the other observations. But if the points come pretty close to the curve, I always consider them. If the observation is certainly a mistake, we do not want it recorded. If we have mistakes we usually can correct them by repeating the observation. We always repeat them in fact in our laboratory work, where we have the apparatus set up, when there is any question. But when you go away from home, or are without all conveniences, sometimes you can only get one set of observations, and then you are not so well off. I am inclined to believe that five per cent. error is pretty good work for a single observation. On some tests I should expect to work closer. But on some testing, if we keep inside of five per cent. or even inside of seven per cent. on single observations, I think we are doing very well. The average is, however, many times better than any observation.

Professor Kinealy: Professor Carpenter's answer brings out what I wanted to bring out. It is extremely difficult, using many instruments, to keep within five per cent.; that is to say, there will be a range of ten per cent. The highest value determined will be five per cent. greater than the average; the lowest will be five per cent. less than the average. In other words, if you make but one experiment, that experiment may be five per cent. too low or five per cent. too high. If you make a series of experiments, the average will give you a nearly correct result, and that result will be nearer correct the greater the number of experiments. The paper is an exceedingly interesting one, and I am sorry that I did not have a copy until this afternoon. It brings out a great many points—points which bear upon the testing of fans, but points which are not directly fan problems. For instance, this point of the anemometer. There are two types of anemometers: one is the Combes type of anemometer that is ordinarily used, and the other is the Biram type. I have had the pleasure of reading the paper which Professor Carpenter will present to you to-morrow morning, and while he does not say it in the paper, it is evident that one anemometer he used is of the Combes type; the other is of the Biram type. That can be told by the curves. He gives the equation of the Combes anemometer on page 71:

$$v = a + bn.$$

That equation is an old one. Morin gives it in his experiments. Professor Carpenter does not, however, tell us how the anemometer was tested. One way is to put the anemometer on a revolving arm, as he mentions; the other way is to walk through a long room, holding the anemometer and measuring the distance walked, by the reading of the anemometer. Another way is a way which I have tested, and which I have discarded. That is to compare one anemometer with another in a current of air. Unfortunately, however, the current of air is never the same at any two points, and the difference in the reading of the anemometers may be due to the error in one anemometer, or it may be due to the difference in the currents of air at different points. I have found that if an anemometer is in pretty good shape, the value of a in the equation is about 50; that is to say, that for the Combes type of anemometer, the ordinary portable anemometer of about two and a half inches in diameter, no registration of the anemometer will be made unless the air has a velocity of about fifty feet per minute, a little less than one foot per second. The value of b varies greatly. Roughly, it is in the neighborhood of " 1," may be $\frac{8}{10}$—may be $1\frac{3}{10}$ Then we come to the next problem, which, perhaps, is the hardest problem which the ventilating engineer has to deal with; and that is, to measure or determine the velocity of the air in a duct. I have had occasion to do some work where it was necessary to determine the velocity of the air in an air duct, and found that it varies at different points. If the Pitot tube be used, the question arises, Where should we hold the end of the Pitot tube in order that we may get with one reading the average velocity of the air through the duct? If we could determine this point, it would save time. If we cannot determine this point, then we must take a series of observations throughout the whole of the cross section of the duct.

You note on page 73 there is an equation:

$$v = k\sqrt{gh}$$

k is a constant; g is the acceleration due to the force of gravity. h is the head in feet of hot air. If b be the velocity in feet per second, the question is, what is k? That question has been discussed for a good many years. European engineers consider

that the pressure produced upon the open end of a Pitot tube, where one end of the tube is in the duct and the other is in the atmosphere, is the head, which, reduced to head in feet of air flowing, will be necessary to give the velocity of the air. In 1897 and 1898, one of my colleagues, Prof. F. E. Nipher, of Washington University, made a large number of experiments to determine whether the head produced by the impact of the air on the open tube was twice the head required to give the velocity to the air. The experiments were made by measuring the velocity between telegraph posts of the train on which he was riding, from the windows of which he passed the open end of the tube. He found that the velocity was equal to that which would be produced by the air flowing under the head equivalent to the pressure. In other words, the head was not twice that due to the velocity, but was exactly equal to that due to the velocity. He made a large number of experiments—how many, I do not know—it is all in print. Then we have the same thing that appears not only in the ventilating tube, but the draft pressure in a chimney—a matter of great importance, not only to ventilating engineers, but to all mechanical engineers. That is the pressure, aside from the pressure due to the impact of the air. Prof. William Thompson, of England, a good many years ago found that the only way to measure the static pressure, not the pressure produced by the moving air, was to put two plates in the neighborhood of eighteen or twenty inches in diameter, I think, very close together, letting air impinge on the edges of those plates. He would thereby reduce or make ineffective, I might say, the pressure due to the velocity, and get the static pressure in the tube. I have laid out a series of experiments which I hope to make some time on boiler chimneys, but unfortunately it is difficult to drill holes eighteen inches in diameter to put large plates in a boiler chimney to determine pressure, at different points. This is in order to determine the pressures at, say, the entrance to the flues, the ends of the tubes and the boiler, and the breeching. I think, however, I have a scheme by which I can avoid the use of large plates and substitute a small tube, and do away with the impact velocity. The draft gauges which are figured here, of course, are of value. The rough gauge ordinarily used—the ordinary "U" tube—is not shown. Of course we all know of that. The next gauge, shown on page

78, is the Carpenter gauge. The next, on page 79, is the Kinealy gauge, and on page 81 is the Barrus gauge. Now, the Kent gauge, on page 83, is very similar to the gauge which was devised in the seventies by Professor Webb, of Stevens Institute, except instead of measuring the difference in pressure by means of a coiled spring, he measured it by the ordinary balance and scale. The open end, which dipped in water, instead of being three or four inches in diameter, was something like fifteen or twenty inches in diameter, or larger, and the force was measured by an ordinary platform scale. That, by means of calculation, was reduced to head in feet of water. The gauge shown on page 84 is, I believe, the Peclet gauge. It has received a number of names since Peclet's time. It has been used by others and modified in different ways. The fact is, my gauge must be considered—whatever may be said as to priority of invention or originality of ideas—my gauge must be considered as simply a perfection of this gauge. I think the paper is a most excellent one. The tests are the kind of tests that we need. Moreover, it is a continuation and a supplement to the paper that was read last year. The question, however, which we must consider most, is the one of the error of a single observation. It is impossible to make a single experiment without having a probable error. We cannot take an indicator card, even with the best indicator on the market, without there being a probable error. We cannot measure the flow of gas through a gas-meter without there being a probable error. We cannot measure the flow of water through a water-meter without there being a probable error. Now, a single experiment is only of value when the probable error is very small. If the probable error be five per cent., then the experiment may be five per cent. below what we should expect, or it may be five per cent. above what we should expect. The fact that a series of experiments agree may simply show that the error has been uniform throughout. It does not necessarily show that each experiment in itself is correct, and the hardest thing that the experimenter has to do is to standardize his instruments, to know where he stands. One other thing which the experimenter must do, is to take care that when he varies one thing he does not vary another, and that the result which he gets is due to the change in the thing which he thought he was changing, and not due to variation in something which he has lost

sight of. We experimenters sometimes get ourselves into trouble. We do the best we can, but the error due to personal observation, the error due to instruments, sometimes becomes very great. I remember one time reading the report of a boiler trial, in which the man had measured up the boiler with an ordinary two-foot rule. The heating surface figured up into the thousandths—four significant figures. Yet he carried his calculations to four places of decimals; that is to say, it was eight significant figures. He did not know anything about errors of one experiment—did not think about it. He might have had an error of five or ten per cent. in any single experiment, as Professor Carpenter says. Yet he carried it out to eight significant figures. Six significant figures makes one in a hundred thousand; eight makes one in ten million. Of course, he was not that close.

Mr. William Kent: I read the paper very rapidly and have not had a chance to study it carefully. But I confess I am somewhat mixed up by what I have heard in the discussion as to how much information this test gives about errors of observation. I would like to ask Professor Carpenter or Professor Kinealy if they were given the opportunity of measuring the air coming in through the register in the wall of this room with any instrument or any measure that they could conveniently get into this room, by anemometers, Pitot tubes, extension devices, or anything of that kind—I would like to have them say how close they could come to the exact amount of air coming into the room?

Professor Kinealy: I would not undertake to tell you how close Professor Carpenter could do it; but I will tell you I would have mighty hard work to make a single experiment and be within five per cent. of the correct figure.

Professor Carpenter: Ten per cent.—twenty per cent.

Professor Kinealy: I say I would have hard work to be within five. I think the probable error would be ten per cent. If I had carefully tested my anemometer and had divided the register face into small areas, and had carefully measured the velocity, and had tested my anemometer immediately afterward, and found that there was no change in the anemometer, I might be within five per cent. But if I bought an anemometer down here at one of the instrument dealers, why, it is impossible to guess what the error would be. I do not know, I am sure. I

tried to buy a pressure gauge once, but I could not get one of the best makers in the country to guarantee me that if I bought a compound gauge it would be as good as one of the standard gauges. I bought two different gauges and then tested them. I stuck to one. I have not used the other much. It is the error in the instrument. Moreover, there is an error in personal readings. When I put an observer on any particular piece of work, I don't change that observer during the test. My personal equation is different from his. Take a planimeter to measure up the area of surfaces; if you buy a good planimeter, a new one, and test it and measure up the area of an indicator card, you are doing exceedingly careful work if you come within one per cent. So that, until we know the error of our readings—the error of our instruments, all down the line—one experiment, one test, shows us very little. Moreover, it may be misleading—it may indicate that a certain thing is so, and another man not so well known, not so old an experimenter, not a man of the same reputation, may come along and make another experiment and get a result that is different. His result is of no value, because somebody else's result does not agree with him.

Mr. Barron: A valuable paper, I think, is one that we learn something from, and I have learned a good deal from this paper of Professor Carpenter's. I learned first that it is simply impossible for me to make a test of fans I put in to get at their efficiency, and to place any reliance on any test I would make. I learned also that fifty per cent. efficiency is about an established fact. I also learned that about one-third the diameter of the fan wheel should be the distance from the scroll or the rear of the fan housing and the periphery of the fan blade. Those are vital features, I think, for us all to know, and to guide the fan manufacturer as well as the man who buys and erects a fan and guarantees the results.

Mr. Stangland: I would like to ask Professor Carpenter if he noticed any difference in the reading of the gauges, due to the distance that those gauges projected into the pipes.

Professor Carpenter Yes, sir. At page 85, the second paragraph, I intended to bring that point out very clearly. I also will refer to some readings which will be shown in the paper which will be read to-morrow, which show very great variations due to that cause. There is variation of both the pressure ve-

locity and temperature, and it makes the matter of getting accurate average results a very difficult one.

Mr. Stangland: Did you fix any point where you considered the current steady?

Professor Carpenter: On page 118 is a diagram which happens to answer that very question for one particular case. It will not do to say that this result is always true, however. The diagram on page 118 is a peculiar one. I will explain it as illustrating this point. The square in the larger line in the figure is a section of pipe divided into smaller squares. There is a diagonal line running down through. Each one of the points which are checked off represents the average value of velocities at that level. For instance, the average velocity of the top section was about 3,300 feet; of the middle section, was 3,700 feet; the average velocity of the whole is opposite the third point from the side and the fifth one down; it is about 4,280. The average of the velocity at the very bottom is about 5,300. Here we had a change in velocity varying diagonally across the section.

Professor Kinealy: Pardon me. That is the paper you are to read to-morrow?

Professor Carpenter: Yes. It is merely used as an illustration of the point referred to. I shall not discuss this point to-morrow, except to mention that there was a change in the velocity in various parts of the cross section. It will be very difficult, I think, to find any point which could be taken as representing average pressures, average velocities, or average temperatures.

Mr. Stangland: Naturally, then, it brings up the question of where we are going to take these readings from.

Professor Carpenter: Take them in all parts of cross section.

Mr. Stangland: If the air was flowing through a pipe at fifteen hundred feet per minute, would you be surprised to find a tendency to a vacuum existing in that pipe?

Professor Carpenter: Last year we found during a test a vacuum four feet from our fan. The observations showed a vacuum of over two inches on the top of the discharge tube, and a pressure of something considerably over an inch on the bottom. We had to rebuild the discharge duct and take our measurements in another place before they were satisfactory. I think we lost two weeks of work because of that phenomenon.

Mr. Blackmore: I would like to ask Professor Carpenter one or two more questions, to bring out more fully the points I referred to before. He makes the statement that when the blades are bent backward they get a greater velocity, when bent forward a greater pressure. I want to ask whether he determined at what angle bent forward or backward they did the best work, either for pressure or for velocity? Also, whether he tried it at different angles, to see which was the most effective, and further, whether he is satisfied in his own mind whether there is any definite point from the periphery of the fan to the housing for the different types, whether bent forward or back, because he gives the general average from the periphery to the scroll, but whether it is affected very much by bending the blade forward or backward, or vice versa?

Professor Carpenter: Mr. Blackmore has raised a point which I intended to bring out in the paper I had originally expected to prepare. We have worked for two years hoping to solve that question, and we have made experiments with an experimental fan of which we could change the form of blades, and have run that fan in a variety of ways; while we may not have determined the form of blade which gives the best results, we have determined that there is a very great difference in the form of the blade, and we think we know pretty nearly what that best form should be. Mr. Blackmore did not quite state the proposition correctly, which makes me think that I misstated it. The fan running with the blade bent forward gives the highest pressure; the fan running with the blade bent backward gives the highest efficiency; that is, it delivers the most air for a given power.

Mr. Blackmore: That is what I understood you.

Professor Carpenter: Now, I think a fan running with the blades bent forward delivers the most air; that is, in other words, it has the most capacity—considerably more capacity than the fan with blades bent backward. But we get that added capacity at the expense of extra power, and hence, it is not the most economical form to use. I think you will notice that the mine people generally run their fans with the tips bent forward, because they are after a high difference of pressure. They get that in the most economical way in that sort of fan. If we want simply high pressure, I should run the fan in that way.

Mr. Blackmore: Are the angles of that bending forward or backward varied much by the velocity of the running of the fan?

Professor Carpenter: No; the angles, I think, are independent of the velocity. The radial blades give results intermediate between those bent forward and backward.

Mr. William Kent: There is one way I know of to measure air, and there are many ways of approximating or guessing at it. That way is hinted at by Professor Carpenter on page 73. But he does not seem to have gone very far with it. He says: "The velocity of air flowing through a duct of given size may also be determined by the use of large measuring tanks, which are alternately filled and discharged with air in such a manner as to give accurately the volume of air flowing. We have recently arranged in Sibley College two large tanks, each holding about three hundred cubic feet, for the purpose of accurately measuring the volume of air discharged." So he does know that that is the way to measure air accurately. But he says: "Up to the present time, this plan has not been used to calibrate anemometers, although it is capable of such use."

Now, the very best way to calibrate anemometers is by such a measuring tank. I have sketched on the board my idea of a measuring tank. Three hundred feet is entirely too small—three thousand is none too large.

Professor Carpenter: Our tanks are so arranged that one goes up automatically, and the other goes down.

Mr. Kent: By a system of counter-weights we can get the air at any pressure. In spring and autumn we can get very uniform temperatures. After we have got your tank and have a watch reading to fractions of a second, we can tell how much air escapes out of that tank by any means provided for it. Having the apparatus in the way which is to be provided at Sibley College, we can make all sorts of other tests, and the first thing I would do if I had such an apparatus, would be to establish the law of flow through orifices. Have the tank full of air, and have steel or brass plates very accurately finished with a sharp edge, say one half an inch, one an inch in diameter, one three or four inches, and one of ten inches. Get a series of standard orifices, calibrate them, and find out their laws. Then test the orifice once for all time by measuring the flow of air through them from the tank. We might use the anemometer opposite these orifices,

and knowing the air coming from these orifices, we could thus test our anemometers. Then we could attach a tube to the orifice and empty the tank at known velocity. We now know there is so much air going through a tube. If we put the anemometers or other instruments in the tube and standardize them under that condition, after a while we will be able to tell something about anemometers, and in the same way we may learn something about Pitot tubes.

Professor Carpenter: In reference to Mr. Kent's suggestion, I would say that we built in Sibley College and used last year almost continuously, on experiments with an air compressor, two tanks arranged something as he has shown there, and both

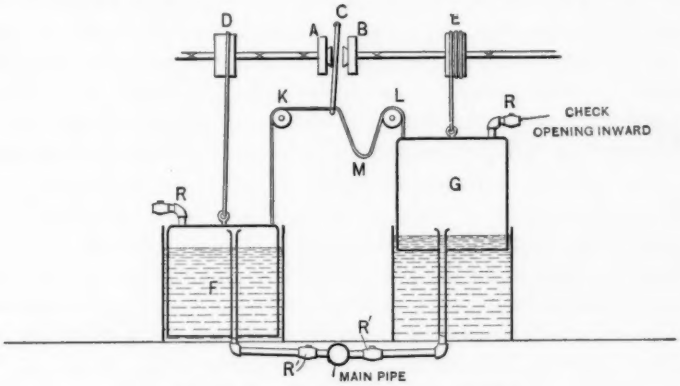


DIAGRAM SKETCH OF TESTING APPARATUS.

counterbalanced and both corrected for pipe displacement, one of which was automatically raised, while the other was automatically falling. That is, when one went down a certain distance, it automatically threw a trip which moved a clutch and stopped descending, and then sent the other tank up, and vice versa, and we found no difficulty with those tanks in measuring all the air that a fifty horse-power air compressor would handle for high pressures. We wanted to determine the amount of slip and leakage there was in a compressor, and thought that would be the only way to do it. That is what we designed those tanks for. But we just have had it freed from those experiments, and now they are arranging it for this purpose.

A diagram sketch of the testing apparatus is shown here. F

and G are two air tanks, bottom side up, immersed in two slightly larger tanks which are nearly filled with water. Tanks F and G are alternately raised and lowered by ropes attached to drums D and E. A and B are two clutch pulleys loose on shafts moving in opposite directions. C is a clutch lever, arranged to throw one of the pulleys in operation by the descending tank pulling the lever so as to cause an up-motion by means of a connecting rope over the supporting and guide pulleys K and L. RR are check valves opening inwards, and R′R′ check valves opening outward. Large rubber balls are used for checks.

Professor Kinealy: The discussion has gotten off of fans to measuring the velocity of air. Now, if Professor Carpenter would carry out Mr. Kent's suggestion and make an experiment, he would find that he cannot very well use this thing to test anemometers. You cannot make a tube so small or so big but what you are going to have differences in velocities. I have taken an anemometer and put on it a paper shield covering one-half the face of the anemometer, to determine what would be the effect. I have then covered three-fourths of the face of the anemometer with a paper shield. The anemometer tends to run, so far as I can find, at a velocity due to the greatest velocity that impinges upon the blade. It does not seem to make any difference whether that greatest velocity is due to blowing through a very small pipe or blowing through a flue 18 by 20 or 18 by 40 inches. Streams of air impinge upon the blade, and the blade tends to take the velocity of the swiftest stream. You can hold an anemometer to a register and move it one inch to one side, and the anemometer will not register—it will stay still. Move it an inch the other way, and the anemometer will run. Now, when you hold an anemometer before a stream of air, the question arises, is that stream of air the same diameter as the diameter of the anemometer? Is it less, or is it greater? Is every particle, every line of that stream of the same velocity, or do the lines vary—do the velocities of the lines vary? The truth is, an anemometer is an instrument of approximation. We use it because we have nothing better. If some of these gentlemen of inventive faculties will invent a better instrument, we will use it. Until then it is simply an instrument for approximating —how close will be determined entirely by the adjustment of your instrument. I have had my instrument taken apart and

put together again, and when it was put together I got, when testing it, a result very different from what I got before. My conclusion has been to always buy an anemometer that has as few wheels and working parts as possible, so that it won't get gummed up, won't stick, and then I test it before I use it, if it is for work of such a character as warrants close observation.

Mr. William Kent: The trouble seems to be that Professor Kinealy has not designed his own anemometers. I knew of a heating and ventilating engineer who designed an anemometer which worked first rate. Instead of being two inches in diameter, it was fourteen. That is a great mistake with all the anemometers. The frictional resistance is a very large source of error in the instrument, because the instrument is of such small diameter. By making anemometers larger and attending to the frictional parts and simplifying the apparatus, I think the anemometer can be made a reasonably correct instrument.

Professor Carpenter: How would it do to make the discharge tube exactly the size of the anemometer, so that every bit of it might go through the anemometer?

Mr. Kent: That might do very well.

Professor Kinealy: I got the best results when measuring the air through an inlet, by dividing the inlet up into squares the length of whose side would be equal to the diameter of my anemometer, about three inches. Simply stuck the anemometer right there, holding it for ten or fifteen seconds, and then moving it to the next. Of course there is a loss due to the movement, but this method has given me the best results.

Mr. Kent: How do you know they are the best? What did you check them against?

Professor Kinealy: I checked them against the method of moving the anemometer slowly back and forth over the face, against the method of dividing the inlet into four parts, five parts, and six parts.

Mr. Kent: You had no other way of measuring the air?

Professor Kinealy: None at all. These results would check with one another better than the results of other methods.

LXXIII.

THE CALCULATION OF DISC FANS.

BY H. EISERT.

(Member of the Society.)

The manufacturers of disc fans in their trade catalogues give the delivering capacities of these fans at free discharge, and cautiously add that for actual service due allowance must be made for any resistance to the flow of air. This would be all very well indeed if, at the same time, a hint were given as to the necessary allowance under given conditions; but on that subject an ominous silence reigns everywhere. While it is true that an experienced engineer knows more or less exactly how much he has to allow under certain conditions, and that in most cases his results may be sufficiently accurate for all practical purposes, it is equally true that any calculations based upon such guess work are at the best very uncertain, not to say unsatisfactory. The truth of this assertion is still more emphasized when the greatly varying delivering capacities and efficiencies of the different fan constructions are taken into consideration.

These facts once acknowledged, it seems but a natural consequence that in cases where a certain effect is to be secured most economically, a calculative determination of the diameter and number of revolutions of the required fan is at least desirable.

The statements in the trade catalogues, giving the probable air deliveries at free discharge in cubic feet for various numbers of revolutions per minute, are, as it might be assumed, the results of experiments, and must be accepted as such.

If, now, a disc fan of a certain size and make delivers Q_o cubic feet of air in one minute at free discharge, when running at the rate of n revolutions per minute, its delivering capacity—that is, the number of cubic feet delivered per revolution at free discharge—can be represented by:

$$q = \frac{Q_o}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{I.}$$

The value of q, therefore, is determinable only by actual experiment; but for obvious reasons may be considered a constant for one and the same fan, though the statements of some catalogue lists imply that the delivering capacity of one and the same fan increases with the increased number of revolutions. This, however, is open to doubt and lacks authentic corroboration.

The velocity at which a certain volume of air passes through a fan depends upon the net area offered for the unobstructed and free passage of the air. While the thickness of the fan blades, as a rule, need not be considered here, the centre hub or disc, by means of which the blades are fastened to the fan shaft, always forms, to a greater or lesser degree, an obstruction to the passage of the air through the fan. As the extreme diameter, d, of such hub, or centre disc, is always known with the make and construction of the fan, the net free area of a fan D feet in diameter is at once determined by:

$$F_o = \frac{D^2\pi}{4} - \frac{d^2\pi}{4} = (D^2 - d^2)\frac{\pi}{4},$$

or, when $\frac{d}{D} = \beta$, more conveniently by

$$F_o = \frac{D^2\pi}{4}(1 - \beta^2) \quad \ldots\ldots\ldots\ldots\ldots\ldots 2.$$

The free area of a disc fan thus being known, the mean velocity v at which a volume of Q cubic feet per minute passes through the fan, can now be expressed by the relation:

$$v = \frac{Q}{60F_o} = \frac{0.02122}{1 - \beta^2}\,\frac{Q}{D^2} \quad \ldots\ldots\ldots\ldots 3,$$

in feet per second, which for delivery at free discharge can be modified to:

$$v_o = \frac{0.02122}{1 - \beta^2}\,\frac{nq}{D^2} \quad \ldots\ldots\ldots\ldots 3a,$$

feet per second.

Though the construction of the different disc fans in the market varies greatly, especially in regard to the form of the blades, their performances can be compared very effectually upon one common basis, and that is their delivering efficiency. By the

delivering efficiency, k, of a disc fan must be understood the proportion of the mean velocity v_0 of the air passing through the fan at free discharge to the mean absolute velocity V of the fan blades. The later can be determined by the following consideration. Assuming the net free area of a fan to consist of a series of infinitely narrow rings of the width (dx), so is the area of any such ring of the mean radius x $(dF_0) = 2x\,\pi\,(dx)$, and its rotating velocity $= 2x\,\pi\,\frac{\pi}{60}$ feet per second. Dividing now the sum of the products of ring areas and rotating velocities, for the values of x between the limits ½d and ½D, by the net free area of the fan, it follows:

$$V = \frac{1}{\frac{D^2\,\pi}{4}(1-\beta^2)} \int_{\frac{1}{2}d}^{\frac{1}{2}D} 2x\,\pi\,\frac{n}{60}\cdot 2x\,\pi\,(dx) = \frac{D\,\pi\,n}{60}\,\frac{2}{3}\,\frac{1-\beta^3}{1-\beta^2} \quad \ldots 4,$$

and as, furthermore,

$$\frac{D\,\pi\,n}{60} = 0.05236\,Dn = v \quad \ldots 5,$$

the circumferential velocity of the fan, finally:

$$V = \tfrac{2}{3}\,v\cdot\frac{1-\beta^3}{1-\beta^2} \quad \ldots 6.$$

According to the previously stated definition, it is therefore:

$$k = \frac{v_0}{V} \quad \ldots 7,$$

which, with the value for v_0 from 3*a*, and that for V from 4, becomes

$$k = 0.6079\,\frac{q}{D^3(1-\beta^3)} \quad \ldots 8.$$

From the latter equation follows:

$$q = 1.645\,k\,D^3(1-\beta^3) \quad \ldots 9,$$

for ascertaining the delivering capacity of a disc fan with free discharge, when its delivering efficiency k is known.

The next property of a disc fan to be ascertained is the maximum pressure which can be produced when running at a certain

number of revolutions. This pressure is identical with that due to the velocity head of the air passing through the fan at free discharge. The latter is readily expressed, according to the well-known formula for falling bodies, by $h = \frac{v_o}{2g}$, as the height of a column of air, when v_o the corresponding mean velocity of the air through the fan as determined by equation 3*a*.

Substituting for v_o its equivalent from equation 7, according to which $v_o = kV$, and introducing for V its value from equation 6, the maximum pressure produced by a fan, as represented by its equivalent at the height in inches of a water column, can then be expressed by:

$$p_m = \frac{0.00024}{1 + \alpha\,(t - 32)} \left[\tfrac{2}{3} k^2 \tau \cdot \frac{1 - \beta^3}{1 - \beta^2}\right]^2,$$

or, as k and β are constants for a given fan construction, more conveniently by:

$$p_m = c_1 \left(\frac{v}{100}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots 10,$$

when

$$c_1 = \frac{\left(\frac{1 - \beta^3}{1 - \beta^2} k\right)^2}{0.9375\,[1 + \alpha\,(t - 32)]} \quad \ldots\ldots\ldots\ldots 11.$$

The coefficient, c_1, depends entirely on the construction of the fan, but varies not so much as to exclude the adoption of a mean value for most of the disc fans now in the market. For $t = +65°$ Fahr. may be taken:

$$c_1 = 1.077\,k^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots 11a,$$

and at that represents a good mean value for exhaust fans.

In actual practice, however, the condition of a perfectly free discharge never exists, because of the unavoidable resistances to the flow of air whenever passing through a system of ducts. Thus a certain part of the maximum pressure produced by a fan will always be expended in overcoming these resistances, leaving only the remainder available for the movement of the air proper. This condition can be represented by the relation

$$p_m = p_v + p_r \quad \ldots\ldots\ldots\ldots\ldots\ldots 12,$$

when p_v the pressure equivalent to the velocity head of the air

actually passing through the fan, and p_r the equivalent in inches of a water column of the resistances of the flow of the air.

Equation 12 shows also that in order to overcome a certain resistance, p_r, the necessary pressure to be produced by the fan must be the greater, the higher the velocity of the air passing through the fan, since the pressure head, respectively its equivalent p_v, necessary to produce a certain velocity, is directly proportional to the square of the velocity, as expressed by

$$p_v = \frac{0.00024}{1 + \alpha\,(t - 32)}\, v^2 \quad \ldots\ldots\ldots\ldots 13.$$

It is, therefore, always advantageous to limit the velocity of the air passing through the fan as much as possible, and assume its value beforehand according to existing or required conditions.

The velocity v of the air thus determined upon, fixes the required diameter D of the fan by equation 3, when transformed into

$$D = \sqrt{\frac{0.02122}{1 - \beta^2}\,\frac{Q}{v}} \quad \ldots\ldots\ldots\ldots 14,$$

which for practical purposes, however, can be modified with sufficient accuracy for all constructions of disc fans, into

$$D = 0.15\,\sqrt{\frac{Q}{v}} \quad \ldots\ldots\ldots\ldots 15.$$

With the diameter of the fan thus ascertained or selected from the list, in case equation 15 should give a dimension that is not a market size, it remains now to determine the required number of revolutions at which the fan is to be run under the given conditions. For this purpose equation 12, after introducing the respective values from equations 3 and 3*a*, is to be transformed into

$$n^2 q^2 = Q^2 + p_r \frac{1 + \alpha\,(t - 32)}{0.00024} \left(\frac{(1 - \beta^2)\,D^2}{0.02122}\right)^2,$$

from which follows

$$n = \frac{10{,}000}{q} \sqrt{\left(\frac{Q}{10{,}000}\right)^2 + c_2\, p_r\, D^4} \quad \ldots\ldots\ldots 16,$$

wherein

$$c_2 = 0.0925 \left(1 + \alpha (t - 32) \right) \left(1 - \beta^2 \right)^2 \ldots\ldots 17,$$

and for which

$$c_2 = 0.09$$

represents a good average value of sufficient accuracy for all practical purposes.

The work done by a fan of this class is equivalent to lifting nq cubic feet per minute to a height equivalent to the maximum pressure (p_m) produced by the fan, and amounts to

$$\frac{1}{\eta_t} \cdot \frac{nq}{60} \cdot \frac{0.0807}{1 + \alpha (t - 32)} \cdot 64.636\, p_m [1 + \alpha (t - 32)]$$

$$= \frac{0.08694}{\eta_t}\, nq \cdot p_m$$

foot pounds per second, when η_t the mechanical efficiency of the fan construction.

Since 550 foot pounds per second constitute one horse-power,

$$p_m = \frac{0.00024}{1 + \alpha (t - 32)}\, v_0^2 = \frac{0.00024}{1 + \alpha (t - 32)} \left(\frac{0.02122}{1 - \beta^2} \frac{nq}{D^2} \right)^2$$

and, by equation 9,

$$q = 1.645\, k\, D^3 (1 - \beta^3),$$

the work of the fan can also be expressed in horse-power by

$$HP_0 = \frac{c_3}{\eta_t} \left(\frac{D}{10} \right)^5 \left(\frac{n}{100} \right)^3 \ldots\ldots\ldots\ldots 18,$$

when

$$c_3 = 7.431 \frac{k^3 (1 - \beta^3)^3}{(1 - \beta^2)^2 [1 + \alpha (t - 32)]} \ldots\ldots\ldots 19.$$

This coefficient, depending entirely on the construction of the fan, is a constant for each make and system of fan, though varying for the different constructions, the average value $c_3 = 7.35\, k^3$ will be sufficiently accurate for all practical purposes.

To this work must be added the loss of energy by friction, due to the axial pressure of the fan shaft. This pressure is directly proportional to the pressure of the air produced by the revolv-

ing system of fan blades. Practical experience has shown that the loss of energy by this cause amounts to from 10 to 20 per cent. of the actual work done by the fan, and depends mainly on the more or less perfect construction of the fan and its mounting.

A further allowance for loss of energy must be made when the fan is driven by a belt. In this case the loss of energy is directly proportional to the number of revolutions, but is nearly a constant for all fans of the same diameter.

Under these considerations the actual power to be transmitted to the fan shaft can be expressed by

$$HP_a = \frac{1 + x}{\eta_t} c_s \left(\frac{D}{10}\right)^5 \left(\frac{n}{100}\right)^3 + n\varphi \ldots\ldots\ldots 20,$$

when $x = 0.10$ to 0.20, and

$\varphi = 0.0011$	0.0015	0.0022	0.0028	0.0062	0.0097	H.P. per revolution.
For D = 3	3½	4	5	6	7	Feet diameter of fan.

For crossed belts the coefficient φ must be increased not less than 25 per cent.

Sometimes it is advisable to provide a motor of sufficient power to allow an increase of the stipulated air supply, in which case the result from equation 20 should be multiplied

By : 1.15	1.33	1.52	1.75	1.95	2.35
For an increase of : 5 p. c.	10 p. c.	15 p. c.	20 p. c.	25 p. c.	33 p. c.

Thus far, these conclusions have been developed strictly according to the well-known laws of physics, and it remains only to show the extent of their applicability in actual practice. Many experiments and tests have been made by various experimenters with disc fans of different constructions, and, as it was to be expected, with greatly varying results. But notwithstanding this seemingly discouraging fact, all of these tests without exception can be compared upon one common basis, whereby such practical data can be obtained as will prove of great value for the calculation of disc fans, as well as for the proper judgment of the actual performances of such fans in operation.

The results from all actual tests demonstrate the unfavorable effect of the " back-lash " or " slip " of the air upon the delivering efficiency of the disc fan whenever discharging against a resistance. This " back-lash," or " slip," of the air in a disc fan is a relative measure for that part of the air that is being discharged at the periphery of the fan at its inlet side, and naturally varies with the construction of the fan and the form of its blades. There is no back-lash perceptible when a fan delivers at free discharge, but it appears as soon as the air is delivered against a resistance, and increases with the offered resistance, reaching a maximum when the fan delivers into a closed receptacle, or when its outlet is closed. In the latter case, when the air delivery should be $Q = 0$, a rapid circulation of air takes place within the fan, independent of the fan movement, the air entering near the centre and leaving at the periphery on the inlet side. Under such conditions it cannot be expected that a disc fan should ever produce the maximum air pressure corresponding to its circumferential velocity, as expressed by equation 10, whenever discharging against a resistance. The difference will be the greater the less the actual air delivery of the fan, as compared with its delivering capacity at free discharge for the same number of revolutions. This disadvantageous property of the disc fans excludes them from practical application for the movement of even small quantities of air against extreme resistances. For the movement of large volumes of air against very low resistances, however, this type of fan will always be the most economical as to the required power, and not less convenient as to its adaptability to local conditions. In connection with ventilating plants disc fans are especially preferred for exhausting purposes, and that with right, inasmuch as the resistances to the flow of the air are usually extremely low, rarely exceeding $\frac{1}{8}$ inch water pressure, a limit up to which the unfavorable effect of the back-lash can be neglected and the proposed formulas for the calculation of the probable performances of disc fans applied with perfect safety for all practical purposes.

DISCUSSION.

Mr. B. Harold Carpenter: I would like to ask under what pressure Professor Kinealy would suggest using the disc fan?

Professor Kinealy: I do not know that I have any pressure to suggest. Mr. Eisert suggests pressures not exceeding one-eighth of an inch of water. In discussion of this paper I would like to say this, that such papers are exceedingly valuable in one way. If a man will gather together all the known facts—all the known things which affect the working of fans, chew them over and digest them, as he must in order to write such a paper, he must bring us ahead a little bit, and every little counts. There are many co-efficients, many factors used in the equations in this paper whose values we do not know. But every time a man gathers together all that is known on a particular subject, and thinks it over and digests it, he must get something which, if published, will help us all, and he will help the man who follows. I cannot see how I can use these equations in designing a plant, in determining the size of a fan to exhaust a certain number of cubic feet of air from a room, or to deliver a certain number of cubic feet of air into a room, because I do not know the co-efficients of this fan and of that fan. I wish Mr. Eisert had published in detail the reasons why the co-efficient " x " on page 108 ought to be $\frac{1}{10}$ to $\frac{2}{10}$ and why equation 5 should be between certain values which he gives here. If he were to do that, that would save me or you the trouble of looking up this subject in after days. For those who design plants, who are not attempting to arrive at exact truths, but must use factors of safety, approximate equations are amply sufficient. We make progress by sitting and thinking over and taking into account everything, great and small, which may affect our results, and it is for that reason that I like to see such papers go on record.

Professor Carpenter: I wish to say a word complimenting such papers as Mr. Eisert's. They are papers which it is impossible to discuss in a meeting. Perhaps it would be impossible to discuss the paper with profit from the fact that there are a number of typographical errors in the formulæ as printed in these proofs, and no one can consider a formula unless it is absolutely correct. Such papers are of value in our proceedings, and will be valuable in after years to refer to. I think the discussion, however, on them is likely to be of very little good, for the reason mentioned.

LXXIV.

CONDENSATION OF STEAM IN BLOWER SYSTEMS OF HEATING.

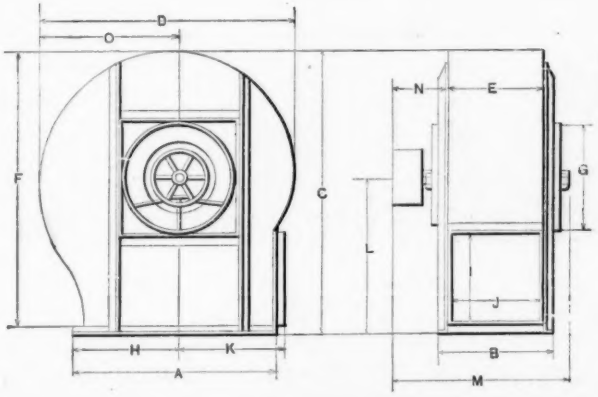
BY R. C. CARPENTER.

(Member of the Society.)

The experiments described in the following paper were made for the purpose of determining the amount of heat transmitted under different conditions of velocity by a blower working under conditions similar to that required for hot-blast heating. The apparatus for this experiment was furnished by the American Blower Company, of Detroit, Mich., and consisted of one of their No. 80 blowers, having a fan wheel 48 inches in diameter. The apparatus furnished consisted of a blower, heater coils, and an engine.

The general appearance and relative position of the parts is shown in the accompanying engraving (Fig. 1).

The blower stands 80 inches high, has a circular inlet 30 inches in diameter, a square outlet 26½ by 26½ inches; the dimensions



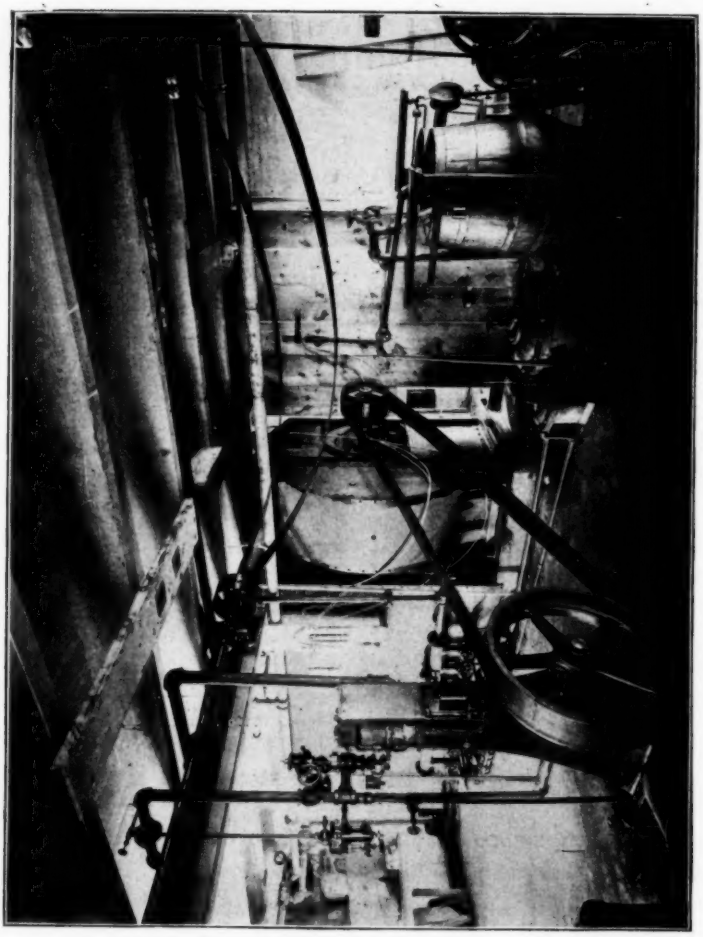


FIG. 1.

corresponding to the symbols on the accompanying drawing of the casing being as follows (see Fig. 2):

Symbol.	Inches.	Symbol.	Inches.
A	55½	I	26¼
B	35	J	26½
C	78¾	K	29½
D	70	L	43¾
E	27¼	M	51½
G	30	N	16¼
H	29	O	38¼

The fan wheel has dimensions marked in Fig. 3. The distance from extremity of fan wheel to nearest point of casing is 6½ inches; to bottom of casing is 18½ inches; to casing at point 45 degrees, back of bottom, 18 inches. Inner face of blades, plain

	DIMENSIONS IN INCHES (FULL SIZE)		
Symbol	Inches	Symbol	Inches
A	55½	I	26¼
B	35	J	26½
C	78¾	K	29½
D	70	L	43¾
E	27¼	M	51½
G	30	N	16¼
H	29	O	38¼

Fig. 2 FAN CASING - No. 80 FAN.

and radial; outer edge for distance of about 4 inches curved so as to stand about 1½ inches back of radius. Estimated radius of curvature, 1½ feet. Number of blades, 8. Outside diameter of fan wheel, 48 inches; inner diameter, 32 inches; width of fan wheel, 16 inches; from centre, 24 inches; at outside circumference, 18 inches. It is revolved in such a direction that the cam of the blade is away from the direction of action.

Each section of the heater (Fig. 4) consisted of three parts: a cast-iron inlet base, an outlet base of similar construction, located on the opposite side, and four series of wrought-iron pipe coils connecting the two, the pipe construction being such that the inner coil of piping is practically the same length as the outer; the intention of the designer being to make the frictional

resistance in all the coils equal. Steam is introduced, as nearly as possible, at the top part of each base; the bottom of the base is dropped down to form a receptacle for whatever condensation

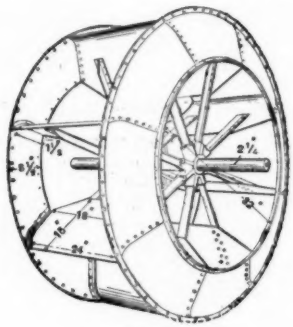


FIG. 3.

may form in the base or run back from the side from which steam is introduced. The bases on the return side of the heater which receive most of the condensation are dripped through

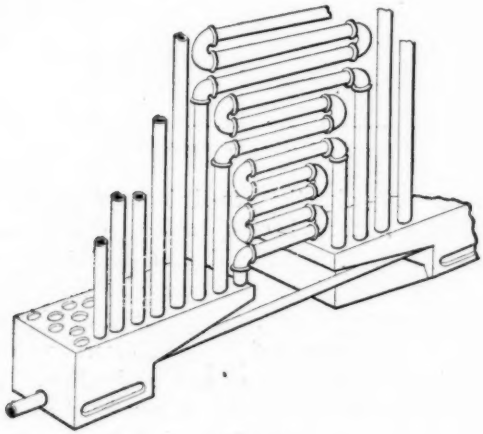


FIG. 4.

the large trap (Fig. 5); those on the steam side through the small one. The heater shown in Fig. 5 has five sections; that tested, had eight.

In the tests of the heater, the condensing water, after its discharge from the traps, was passed through a cooling coil immersed in a tank of water, and then discharged in a barrel on scales, in which it was weighed. Each of the eight sections of the heater contained, by measurement, 171 linear feet of inch pipe, and, making allowance for the elbows and bends, contained 180.85 square feet of heating surface. Each section was pro-

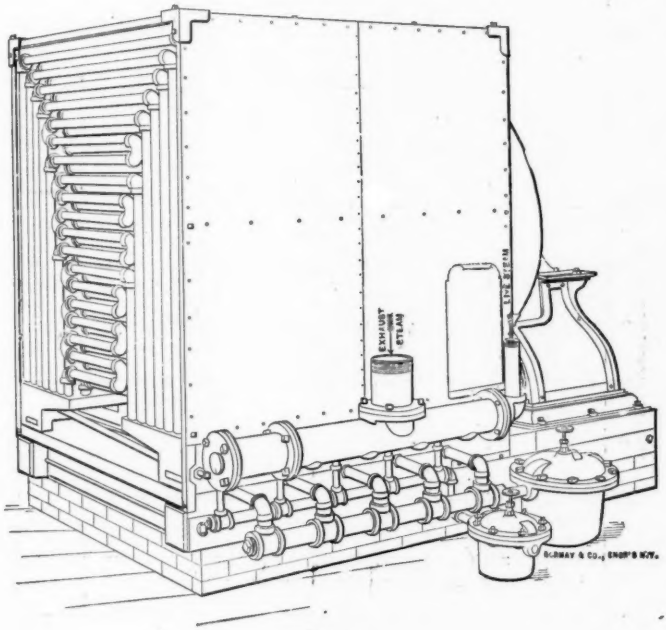


FIG. 5.

vided with valves on both steam and return pipe, so that any portion of the heating surface could be used as desired. Section 5 of the heater contained a broken fitting which was difficult to remove, and all the tests recorded were made without that section in use.

The blower was driven by a vertical engine 6 inches by 6 inches, which was operated with fixed cut-off and throttling governor. It was arranged to drive the fan with an open belt, and was capable of developing about 18 horse-power.

The investigation was conducted to determine the following: (a) The effect of change of pressure in the steam coils upon

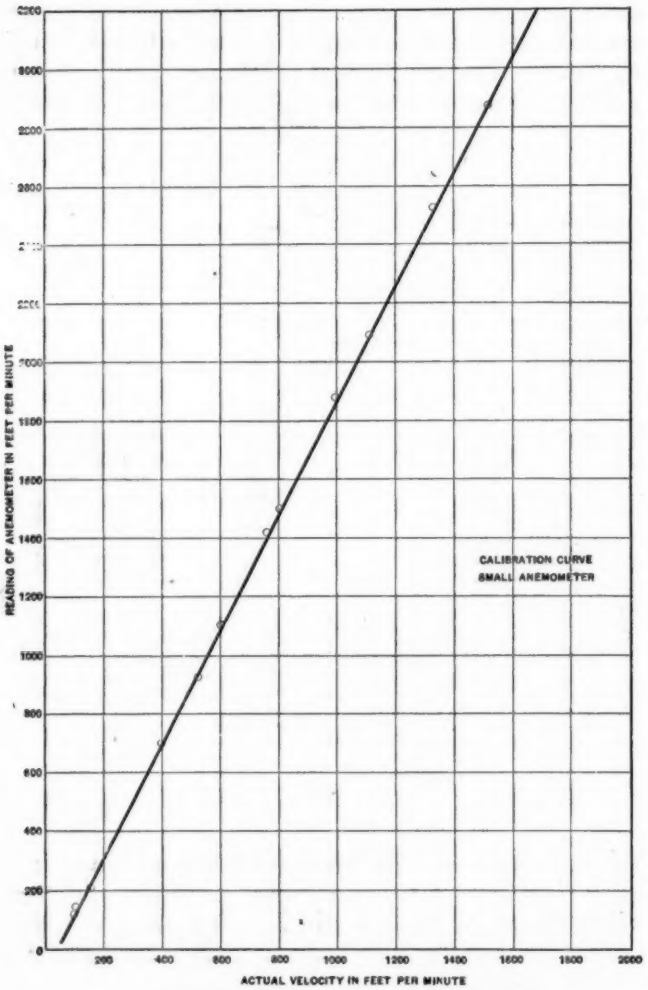


Fig. 6 · CALIBRATION CURVE SMALL ANEMOMETER

the amount of heat given up to the air, other conditions remaining constant. This was determined from the data obtained from 15 trials, with five different amounts of heating surface and

three different steam pressures, namely, 15 pounds, 40 pounds, and 60 pounds.

(b) The effect of varying the amount of heating surface upon the heat given up to the air, the pressure of steam in the coils and velocity of air through them remaining constant; this was

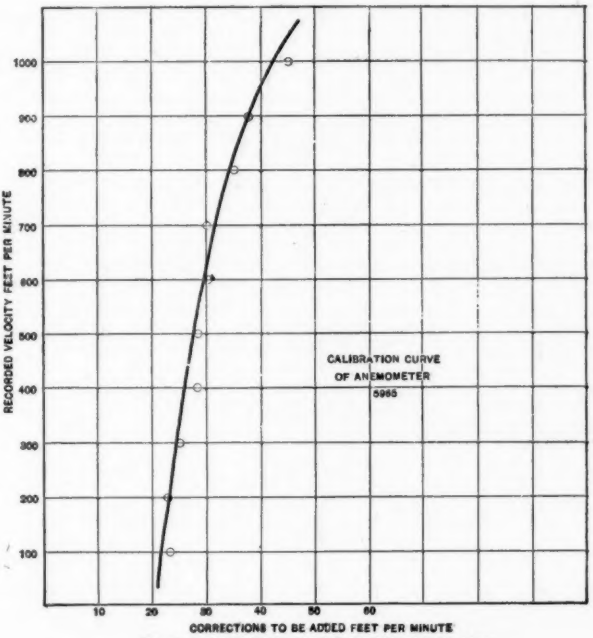


Fig. 7 CALIBRATION CURVE ANEMOMETER 5965

deduced from 15 tests, using five different amounts of heating surface.

(c) The effect of varying the velocity of the air through the coils upon the heat given up by them.

(d) Condensation of steam per hour per square foot of heating surface at the various pressures of steam.

(e) Tests of the blower used under different conditions.

The writer was assisted in making these tests by Prof. A. T. Breugel, Mr. Whittle, a graduate student in 1896; Mr. Alfred Hulburt and Mr. E. K. Muller, graduates of Sibley College in 1897.

In measuring the velocity of air, two anemometers and several Pitot tubes were used. The cross section of the casing at the entrance of the air to the heater was subdivided into small squares, and the average velocity determined by the anemometer reading was obtained by placing the anemometers successively in these various sections and taking the average of the results. The Pitot tube was used to determine the velocity in the dis-

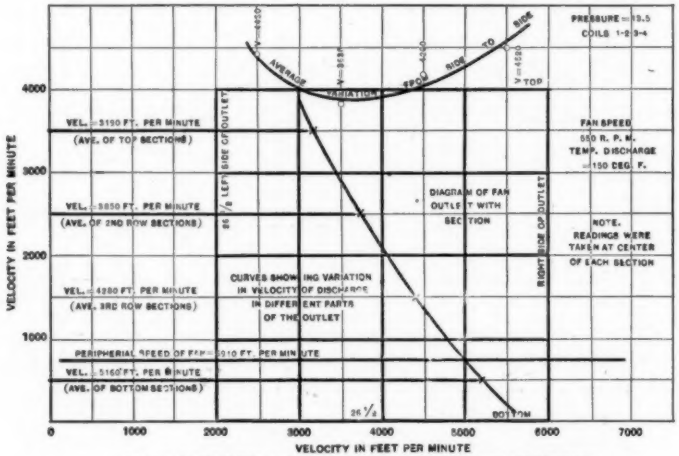


Fig. 8 - VARIATION IN VELOCITY OF DISCHARGE IN DIFFERENT PARTS OF THE OUTLET

charge pipe at some little distance from the fan wheel and in a position where the velocity was too great for the use of the anemometer. The two anemometers used differed considerably in their readings. Both instruments were calibrated, and it may be interesting to note the results of the calibration. It will be noted that the small anemometer had a very large error; for instance, when the instrument scale reading was 2,000 feet per minute, the actual velocity, as determined by the calibration, was only 1,035. Anemometer No. 50,965 was very nearly correct. To the reading of the anemometer it was necessary to add quantities represented by the numbers given at the bottom of the diagram. The comparison of the corrected results, when using the Pitot tube at the smaller cross section and for measuring the higher velocity, was generally very satisfactory as compared with the corrected readings of the anemometer.

The results of each test showed a very considerable variation in velocity of discharge in different parts of the same cross section of the outlet. The amount of this variation is shown graphically in Fig. 8 for one of the tests; the peripheral speed of the fan being 6,910 feet per minute. The velocity of the air varied from 3,190 as the average in the top sections of the outlet to

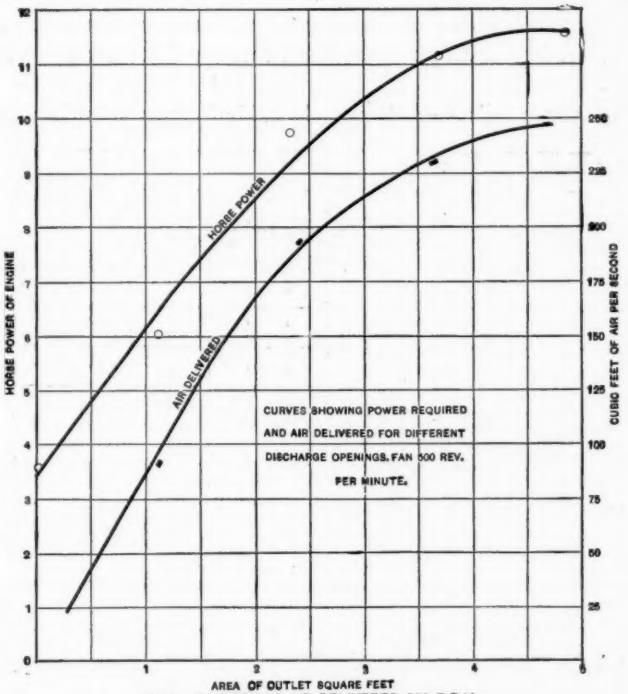


Fig. 9 POWER AND AIR DELIVERED 500 R.P.M.

5,160 feet per minute as the average in the bottom sections. The variation of the sections from side to side was less, being from 4,430 at one side, to 3,630 at the centre. The highest velocity was found nearest the bottom of the outlet and on the side opposite the inlet of the fan.

The effect of varying the area of outlet upon the horse-power required to operate the fan, and also upon the air delivered, is shown in Fig. 9; the amount of power required when the outlet was entirely closed being 3.5 horse-power, the amount re-

quired when the outlet was fully open being 11.6 horse-power, the fan running constantly at a speed of 500 revolutions per minute.

The variation in speed of fan produced by varying the size of the outlet when a constant power was applied to drive it, is shown graphically in Fig. 10, from which it will be noted that the speed increases at a nearly uniform rate when the outlet is being reduced from 4.8 to 2 square feet, but from that point the speed increases with an accelerated rate for further decrease of outlet.

The amount of air discharged in cubic feet per hour is shown

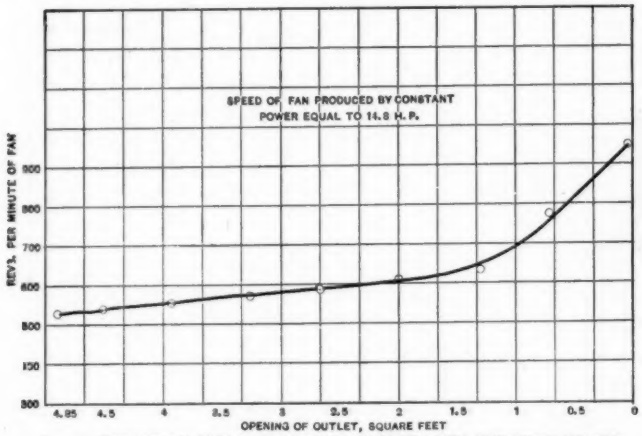


Fig. 10 EFFECT ON SPEED OF VARYING OUTLET WITH CONSTANT POWER

graphically in Fig. 11, the fan being driven at different speeds. During all these tests the air was drawn over eight heater coils at a temperature of 70 degrees Fahr. by suction, and discharged freely into the atmosphere. It will be noted that the amount of air discharged is almost exactly proportional to the speed. The writer gave as a rule for determining the capacity of a fan of usual proportions, at the last meeting of the Society, the following: "The capacity of a blowing fan, expressed in cubic feet of air delivered, is equal to the cube of the diameter of the fan wheel in feet multiplied by the number of revolutions multiplied by a coefficient having a value depending upon the back pressure of from 0.4 to 0.6." Multiplying the cube of the diameter of this fan wheel by the number of revolutions per hour, we find

that the results should be multiplied by 0.555 to give the correct discharge as shown on the diagram.

The effect of varying the number of coils in use, and also the steam pressure, on the heat absorbed by the air per square foot per hour is shown in Figs. 12, 14, and 15. From this it is seen that the amount of heat transferred per square foot of surface diminishes rapidly with increase in the number of sections from

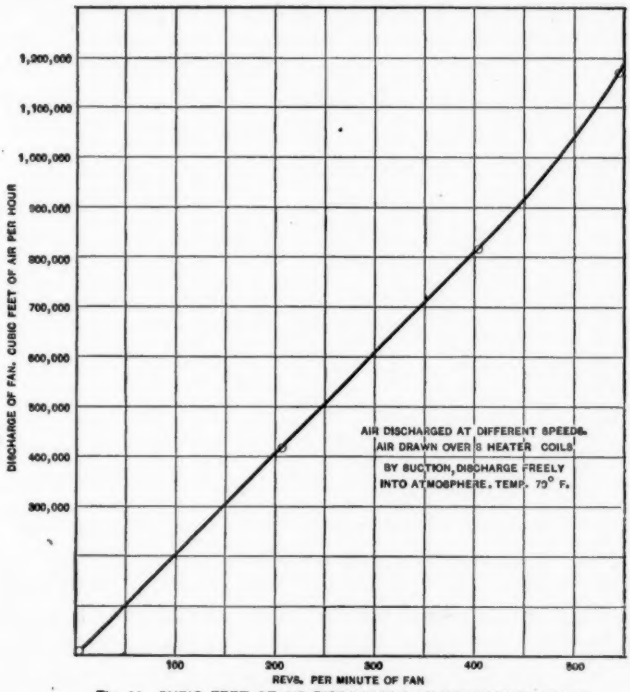


Fig. 11 CUBIC FEET OF AIR DISCHARGED AT DIFFERENT SPEEDS

one to three (4 to 12 coils), after which the transfer of heat remains essentially constant.

A series of tests were made, operating the fan at different speeds, the results of which are shown in Fig. 13. From this diagram it is seen that the heat transmitted varies nearly with the square root of the velocity of the air, and expressed in thermal units is approximately equal to 150 + 33 times the square root of the number of revolutions per minute.

Fig. 14 shows the relation between the heat given off, ex-

pressed in British thermal units per square foot per hour, for each degree difference in temperature between the steam and the air for various amounts of heating surface. The same diagram also shows the rise of temperature of the air in passing through the coils, due to different amounts of heating surface. During all the tests shown on this diagram the steam pressure was maintained between 13 and 14 pounds; the fan was operated at about 400 revolutions per minute, thus giving an air velocity of about 450 feet per minute for the air passing the heating coils. From the scale on the left of the diagram it is noticed that the number of heat units per degree difference of temperature transmitted

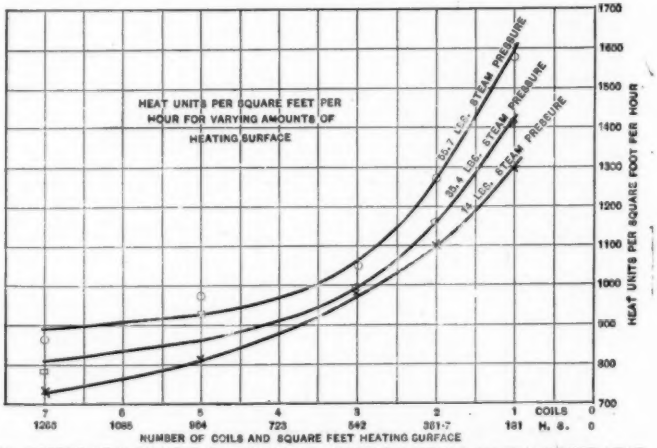


Fig. 12 EFFECT OF VARYING THE AMOUNT OF HEATING SURFACE ON TRANSMITED HEAT

by the heater per square foot per hour, varies from something over 8.5 when one section of the heater (4 coils) was in use, to slightly over 6 when seven sections (28 coils) were in use. The rise in temperature of the air shown by the scale on the right varies from 47 to 108 degrees.

Fig. 15 shows the relation between the temperature of the discharged air, the steam, and the entering air for different amounts of heating surface, the fan speed being maintained at 400 revolutions, the velocity of entering air at about 450 feet, and the steam pressure from 13 to 14 pounds. It is noted by this diagram that the temperature of air increases rapidly with an increase in heating surface up to about three sections (12 coils), after which it increases slowly.

Fig. 16 shows the relation between the temperature of entering steam and the heat units given off per square foot per degree of difference of temperature per hour. It will be noted from this diagram that the heat transfer per degree difference of temperature was more active at the lower temperatures of steam than at the higher. This is seen to be the case for each series of tests in which different amounts of heating surface were used. The difference, however, was not so marked during the series when five sections were in use, which was probably due to some existing condition that was not, at the time, taken into account.

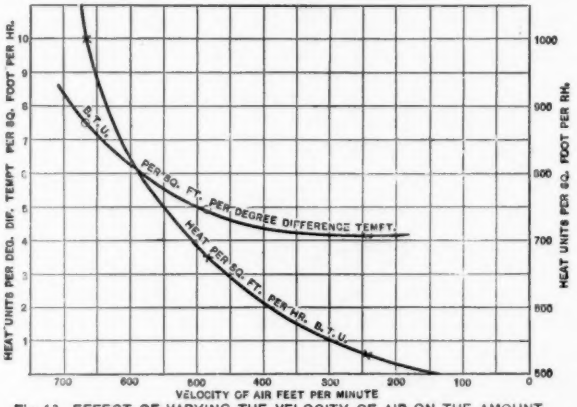

HEAT UNITS PER DEG. DIF. TEMPT PER SQ. FOOT PER HR.
HEAT UNITS PER SQ. FOOT PER HR.
B.T.U. PER SQ. FT. PER DEGREE DIFFERENCE TEMPT.
HEAT PER SQ. FT. PER HR. B.T.U.
VELOCITY OF AIR FEET PER MINUTE

Fig. 13 EFFECT OF VARYING THE VELOCITY OF AIR ON THE AMOUNT OF HEAT LIBERATED. STEAM PRESSURE 13.3 LBS. ENTERING AIR 73° FAR.

Each curve in this diagram shows a series of tests made with different amounts of heating surface.

Fig. 17 is an interesting diagram, showing the relation between the delivery of the fan in cubic feet per minute and areas of openings in the discharge chamber for different speeds. It will be noted, in each case, that the delivery is proportional to the speed, and, furthermore, that the delivery is decreased by decreasing the size of outlet, which is equivalent to interposing resistances in the pipe line.

Fig. 18 shows the relation between the area of outlet and the discharge in cubic feet per minute for different openings for a fan speed of 400 revolutions per minute; also the corresponding pressure in inches of water.

From this diagram it will be noted that the volume discharged varies within the limits of the experiment directly in

proportion to the area of outlet; also that the pressure diminishes as the outlet increases. During these tests the fan was operated at 400 revolutions per minute, the area of inlet into fan chamber being 4.9 square feet.

The following tables give the average results of the various

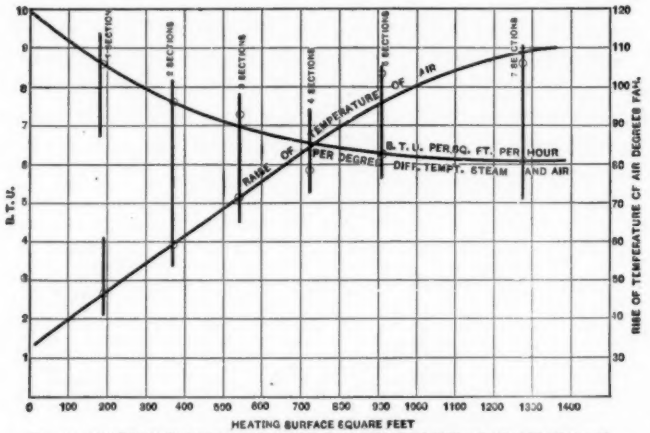


Fig. 14 - DIAGRAM SHOWING B.T.U. PER SQUARE FOOT PER HOUR FER DEGREE DIFFERENCE TEMPERATURE STEAM AND AIR, FOR VARIOUS AMOUNTS OF HEATING SURFACE. STEAM PRESSURE 13 TO 14 LBS. REVOLUTIONS OF FAN 400 PER MINUTE. AIR VELOCITY 450 FEET PER MINUTE.

tests discussed. Tests numbered from 1 to 15 were made with the fan running at about 400 revolutions per minute, and a pressure in the discharge pipe of about 0.35 inch of water and an equivalent opening of 20 by 20 inches.

AVERAGE RESULTS OF TEST WITH 1 SECTION. 180.85 SQ. FT. OF HEATING SURFACE.

Number of Run.	1	2	3
1. Mean pressure in coils, pounds	12.62	35.5	54
2. Temperature of steam, degrees Fahr.	244.1	280.5	302
3. Total steam condensed per hour, pounds	293	294	320
4. Per square foot steam condensed per hour, pounds	1.4	1.64	1.7
5. " " " B. T. U. per hour	1,340	1,413	1,582
6. Temperature of air received, degrees Fahr.	65	65	65.9
7. " " " delivered, " "	112	112	114.2
8. " " " mean, " "	88.5	88.5	90.05
9. " " " increase, " "	47	47	48.3
10. Expansion of air by heating	1.08	1.09	1.085
11. Velocity of air entering coils, feet per minute	511	485	507
12. Revolutions of fan per minute	400	400	404
13. Peripheral speed of fan	5,020	5,026	5,070
14. Difference temperature between steam and entering air	179.1	215.5	236.1
15. " " " " " mean air	155.6	192.0	212 0
16. B. T. U. per sq. ft. per hour for difference temperature (14) per day	7.5	6.6	6.8
17. " " " " " " " (15) " "	8.63	7.4	7.49
18. Probable B. T. U. per hour entering air zero per square foot H. S.	1,615	1,655	1,835
19. " steam condensed " " " " " pounds	1.67	1.72	1.90
20. Volume of air received, cubic feet per hour	882,000	829,000	867,000
21. Velocity in discharge duct, feet per minute	2,860	3,090	3,140
22. Ratio velocity of air to peripheral velocity of fan	0.565	0.611	0.622

AVERAGE RESULTS, TESTS OF HEATER WITH 2 SECTIONS. 361.7 SQ. FT. OF HEATING SURFACE.

Number of Run.	4	5	6
1. Mean pressure in coils, pounds	13.1	35.5	57
2. Temperature of steam, degrees Fahr	246.3	281	302.7
3. Total steam condensed per hour, pounds	458	465	511
4. Per square foot steam condensed per hour, pounds	1.27	1.28	1.42
5. " " " B. T. U. per hour	1,108.5	1,167	1,267
6. Temperature of air received, degrees Fahr	71.17	72.7	73.8
7. " " " " delivered, " "	130	144.7	147
8. " " " mean, " "	100.6	108.7	110.4
9. " " " increase, " "	58.8	72	73.1
10. Expansion of air by heating	1.115	1.135	1.138
11. Velocity of air entering coils, feet per minute	517	489	494
12. Revolutions of fan per minute	400	400	404
13. Peripheral speed of fan	5,026	5,026	5,070
14. Difference of temperature between steam and entering air	175.1	218.3	248.9
15. " " " " " " " mean air	146.2	172.3	192.3
16. B. T. U. per sq. ft. per hour for difference temperature (14) per day	6.34	5.34	5.07
17. " " " " " " " (15) " "	7.56	6.78	6.59
18. Probable B. T. U. per hour entering air zero per square foot H. S.	1,380	1,410	1,510
19. " steam condensed " " " " " " pounds	1.43	1.46	1.56
20. Volume of air received, cubic feet per hour	884,000	835,000	845,000
21. Velocity in discharge duct, feet per minute	3,270	3,140	3,460
22. Ratio velocity of discharge to peripheral velocity	0.645	0.625	0.682

AVERAGE RESULTS, TESTS OF HEATER WITH 3 SECTIONS. 542.6 SQ. FT. OF HEATING SURFACE

Number of Run.	7	8	9
1. Mean pressure in coils, pounds	14	34.5	56.5
2. Temperature of steam, degrees Fahr	245	280	303.7
3. Total steam condensed per hour, pounds	575	591	647
4. Per square foot steam condensed per hour, pounds	1.05	1.09	1.19
5. " " " B. T. U. per hour	986	993	1,053
6. Temperature of air received, degrees Fahr	74	73	70.2
7. " " " " delivered, " "	145.5	153	166.2
8. " " " mean, " "	110	113	118.2
9. " " " increase, " "	71.5	80	96
10. Expansion of air by heating	1.13	1.15	1.18
11. Velocity of air entering coils, feet per minute	506	452	488
12. Revolutions of fan per minute	400	404	400
13. Peripheral speed of fan	5,026	5,040	5,040
14. Difference of temperature between steam and entering air	171	207	233.5
15. " " " " " " " mean air	135	167	185.5
16. B. T. U. per sq. ft. per hour for difference temperature (14) per day	5.78	4.8	4.48
17. " " " " " " " (15) " "	7.31	5.95	5.7
18. Probable B. T. U. per hour entering air zero per square foot H. S.	1,258	1,475	1,608
19. " steam condensed " " " " " " pounds	1.35	1.53	1.67
20. Volume of air received, cubic feet per hour	865,000	782,000	834,000
21. Velocity in discharge duct, feet per minute	3,460	3,080	3,110
22. Ratio of velocity in discharge duct to peripheral velocity	0.68	0.61	0.618

AVERAGE RESULTS OF HEATER WITH 5 SECTIONS. 904.4 SQ. FT. OF HEATING SURFACE.

Number of Run.	10	11	12
1. Mean pressure in coils, pounds	13	34	53.2
2. Temperature of steam, degrees Fahr	245	279	300.7
3. Total steam condensed per hour, pounds	764	937	1,014
4. Per square foot steam condensed per hour, pounds	0.84	1.04	1.12
5. " " " B. T. U. per hour	800.6	931.8	991.0
6. Temperature of air received, degrees Fahr	66.25	70.6	74.9
7. " " " " delivered, " "	169.75	191.5	203.7
8. " " " mean, " "	118	131	139.3
9. " " " increase, " "	103.5	121	128.8
10. Expansion of air by heating	1.19	1.23	1.24
11. Velocity of air entering coils, feet per minute	456	446	430
12. Revolutions of fan per minute	400	404	402
13. Peripheral speed of fan	5,026	5,050	5,050
14. Difference of temperature between steam and entering air	179	208.4	225.8
15. " " " " " " " mean air	127	148	161.4
16. B. T. U. per sq. ft. per hour for difference temperature (14) per day	4.5	4.5	4.42
17. " " " " " " " (15) " "	6.32	6.30	6.15
18. Probable B. T. U. per hour entering air zero per square foot H. S.	1,007	1,140	1,220
19. " steam condensed " " " " " " pounds	1.05	1.19	1.27
20. Volume of air received, cubic feet per hour	781,000	762,000	736,000
21. Velocity in discharge duct, feet per minute	3,150	3,115	3,140
22. Ratio of velocity in discharge duct to peripheral velocity	0.62	0.615	0.62

AVERAGE RESULTS OF HEATER WITH 7 SECTIONS. 1,266 SQ. FT. OF HEATING SURFACE.

Number of Run.	13	14	15
1. Mean pressure in coils, pounds	13.2	58.3	53.6
2. Temperature of steam, degrees Fahr	246.3	291	310
3. Total steam condensed per hour, pounds	970	1,088	1,231
4. Per square foot steam condensed per hour, pounds	0.76	0.865	0.97
5. " " " B. T. U. per hour	703.3	759	852
6. Temperature of air received, degrees Fahr	77	78	75.7
7. " " " delivered, " "	182.5	215	226.5
8. " " " mean, " "	129.5	146.5	151.1
9. " " " increase, " "	105.5	137	150.9
10. Expansion of air by heating	1.18	1.25	1.28
11. Velocity of air entering coils, feet per minute	486	452	449
12. Revolutions of fan per minute	400	402	403
13. Peripheral speed of fan	5,026	5,040	5,065
14. Difference of temperature between steam and entering air	149.3	213	234.3
15. " " " " " " mean air	116.5	144.5	159.6
16. B. T. U. per sq. ft. per hour for difference temperature (14) per day	4.7	3.65	3.65
17. " " " " " " (15) " "	6.05	5.36	5.35
18. Probable B. T. U. per hour entering air zero per square foot H. S.	937	987	1,055
19. " steam condensed " " " " " " pounds	0.965	1.02	1.09
20. Volume of air received, cubic feet per hour	800,031	772,500	767,000
21. Velocity in discharge duct, feet per minute	3,150	3,140	3,160
22. Ratio of velocity in discharge duct to peripheral velocity	0.625	0.622	0.625

AVERAGE RESULTS OF HEATER WITH 4 SECTIONS. 723.4 SQ. FT. OF HEATING SURFACE.

Number of Run.	16	17	18
1. Mean pressure in coils, pounds	13	12.5	12.7
2. Temperature of steam, degrees Fahr	245	244	246.5
3. Total steam condensed per hour, pounds	769	518	405
4. Per square foot steam condensed per hour, pounds	1.06	0.72	0.56
5. " " " B. T. U. per hour	1,003.6	673.3	529.8
6. Temperature of air received, degrees Fahr	73.2	73.33	73.5
7. " " " delivered, " "	150.3	152.3	162.75
8. " " " mean, " "	111.7	112.8	118.12
9. " " " increase, " "	77	79	89.3
10. Expansion of air by heating	1.14	1.15	1.16
11. Velocity of air entering coils, feet per minute	664	482	246
12. Revolutions of fan per minute	552	404	204
13. Peripheral speed of fan	6,440	5,070	2,568
14. Difference of temperature between steam and entering air	172.8	140.7	143
15. " " " " " " mean air	133.3	131.2	128.3
16. B. T. U. per sq. ft. per hour for difference temperature (14) per day	5.83	4.82	3.71
17. " " " " " " (15) " "	7.53	5.16	4.13
18. Probable B. T. U. per hour entering air zero per square foot, H. S.	1,275	815	683
19. " steam condensed " " " " " " pounds	1.33	.845	.705
20. Volume of air received, cubic feet per minute	18,950	13,750	7,066
21. Velocity in discharge duct, feet per minute	4,210	2,980	1,505
22. Ratio of velocity in discharge duct to peripheral velocity	0.65	0.59	0.59

Conclusions.—From the fact that these tests represent only the results to be obtained by fans working under the same conditions, it is not safe to draw broad conclusions as applying to all cases with accuracy. The general conclusions which can be drawn from these tests seem to be as follows:

The effect of change of pressure of the steam which is used in the steam coil increases the total amount of heat given off, but does not increase the heat transfer in proportion to the increase of temperature of the steam, and hence it is not advisable to use, for the purposes of hot-blast heating, steam of any greater pressure than that necessary to insure circulation through the coils. The limit of steam pressure which may be

used with success cannot be deduced from the experiments quoted.

The effect of increasing the velocity of the air increases its capacity to take up heat an amount which increases at a greater rate than the square root of the increase of velocity. This would indicate that the capacity of a given system for hot-blast heating would be increased by increasing the speed of the fan, both as to the quantity of air supplied and as to the amount of heat taken

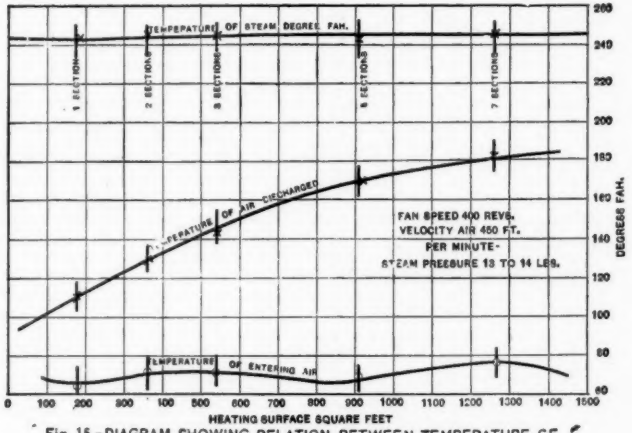


Fig. 15 - DIAGRAM SHOWING RELATION BETWEEN TEMPERATURE OF DISCHARGED AIR AND HEATING SURFACE.

up. The amount of heat taken up, is not however, sufficient to keep the air at a constant temperature, although the fall in delivery temperature, due to increase of velocity, may be slight. This is illustrated in tests Nos. 16, 17, and 18. In each of these tests the air was received at practically the same temperature, that of 73 degrees; the same heating surface was used; the velocity was in the three tests, respectively, 246, 482, and 664 feet per minute; the corresponding discharge temperature being, respectively, 163, 152, and 150 degrees Fahr., which shows a very small drop in delivery temperature due to an increase in velocity of air to nearly three times its first velocity.

The condensation of steam per hour varies with the amount of heating surface and the number of coils over which the air flows. It would seem that the conclusions from the test would be that the limit of economic heater construction would limit

the number of coils with which the air comes in contact to some point in the region from 12 to 20, as the steam which is condensed for heating purposes is obtained principally from the coils mentioned. The amount of steam which would be condensed by passing the air over 3 to 4 sections (12 to 16 coils) with entering air at zero temperature and discharge air about 140 degrees would be, it is computed, equal to 1.3 pounds

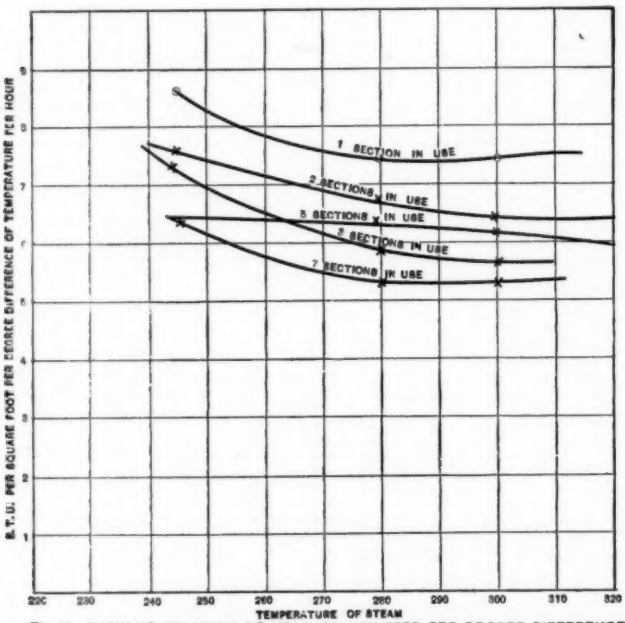

B.T.U. PER SQUARE FOOT PER DEGREE DIFFERENCE OF TEMPERATURE PER HOUR
1 SECTION IN USE
2 SECTIONS IN USE
3 SECTIONS IN USE
5 SECTIONS IN USE
7 SECTIONS IN USE
220 230 240 250 260 270 280 290 300 310 320
TEMPERATURE OF STEAM

Fig.16 - SHOWING RELATION OF HEAT TRANSMITTED PER DEGREE DIFFERENCE TEMPERATURE TO TEMPERATURE OF STEAM.

of steam per square foot of heating surface per hour (equivalent to about 1,260 feet units), from a heater situated under conditions similar to those which existed at the time of making the test.

Taking the specific heat of air as 0.238, it will require 33.3 British thermal units to warm one pound of air from a zero temperature to 140 degrees. From this the amount of heat given off from one square foot of heating surface would warm 37.8 pounds from zero to 140 degrees, or it would warm 44 pounds

from zero to 120 degrees. The volume of air for ventilation purposes may better be calculated at about the temperature of use, which is usually 70 degrees, at which temperature each cubic foot weighs 0.075 pound. Reducing these results to cubic feet on the above basis, we find that one square foot of heating sur-

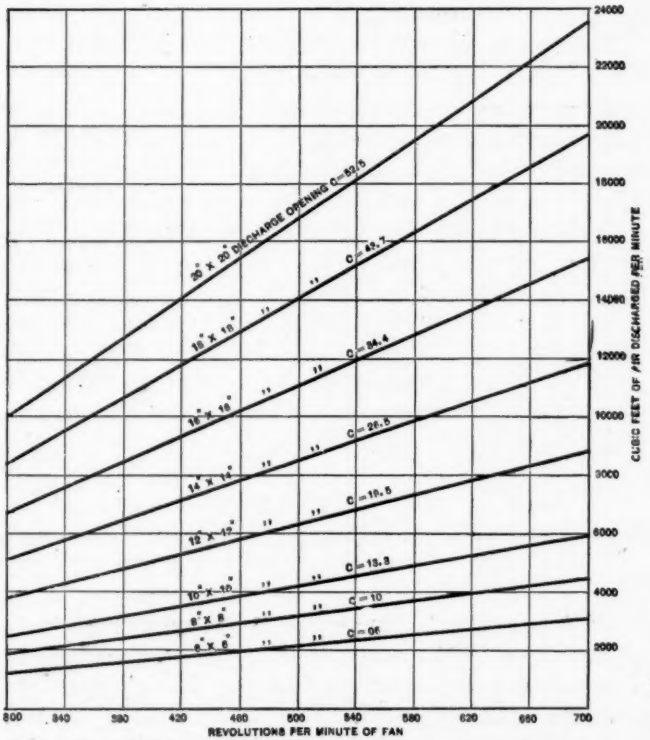


Fig. 17- RELATIONS BETWEEN REVOLUTIONS PER MINUTE AND DISCHARGE FROM FAN FOR VARIOUS OPENINGS IN DISCHARGE CHAMBER.

face would warm 504 cubic feet (measured at 70 degrees) per hour from zero to 140 degrees, or 587 cubic feet from zero to 120 degrees. This is, respectively, 8.4 and 9.8 cubic feet per minute.

For many purposes it is convenient to reckon the heating capacity as based on the equivalent lengths of inch pipe in the heater. To obtain this we would need to divide the above re-

sults by 2.9. Reducing, as explained, we find on this basis that the equivalent of each linear foot of one-inch pipe in the heater, would warm 2.9 cubic feet of air from zero to 140 degrees, or 3.38 cubic feet of air from zero to 120 degrees.

The various results which have been given show the effect of varying different conditions with respect to capacity and efficiency of the blower used.

The capacity, when delivering into free air, is equal to the

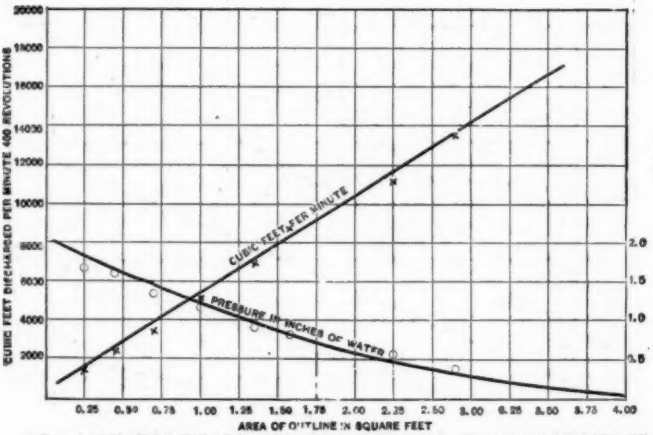

CUBIC FEET DISCHARGED PER MINUTE 400 REVOLUTIONS
CUBIC FEET PER MINUTE
PRESSURE IN INCHES OF WATER
AREA OF OUTLINE IN SQUARE FEET
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 3.00 3.25 3.50 3.75 4.00
2.0
1.5
1.0
0.5

Fig. 18—RELATION BETWEEN AREA OF OUTLET IN SQ. FT. AND DISCHARGED OF FAN. FAN RUNNING AS 400 REVS PER MINUTE AREA OF FAN INCHES 4.91 SQ. FT.

cube of the diameter in feet multiplied by the number of revolutions multiplied by the coefficient 0.555.

For other openings than that for free delivery, we find the following coefficients for D^3n:

Opening. Inches.	Coefficient.	Pressure Inches of Water for 400 Rev. of Fan above Atmosphere.
26 × 26	0.555	0
20 × 20	0.225	0.35
18 × 18	0.437	0.56
16 × 16	0.344	0.82
14 × 14	0.265	0.91
12 × 12	0.195	1.15
10 × 10	0.133	1.37
8 × 8	0.100	1.54
6 × 6	0.060	1.67
2 × 2	.....	1.87

The investigations show that the pressure produced by the fan can be expressed by the following formula, in which v =

velocity of tip of fan in feet per second; o equals the area of the outlet in square feet; i equals the area of inlet in square feet (equals 4.7 square feet for the condition when the barometer reads 29.92 inches of mercury).

$$p = \left[15.3\sqrt{\frac{v^2}{6{,}400} + 58.62} - 117.2\right]\left(1 - \frac{o}{i}\right)^2.$$

DISCUSSION.

Mr. Albert A. Cary: Mr. President, in referring to Fig. 8 I see something that strikes me rather strangely. If the upper curve marked "Average variation from side to side" was inverted it would seem to confirm previous investigation. In other words, the friction at the side of the opening is supposed to account for something and the freest air is supposed to be in the centre of the opening. I have not had time to go over this paper as carefully as I would have liked to; but that is one point that struck me as the professor was reading it.

Professor Carpenter: The figure is correct, however. It is accounted for by a sort of an eddy in the centre of the pipe.

Mr. Kent: Is that a square pipe?

Professor Carpenter: It is.

Mr. Kent: The highest velocity was down in the right-hand point, and the lowest up in the left-hand point.

Professor Carpenter: Yes.

Mr. Kent: That will vary with every pipe, won't it?

Professor Carpenter: Yes, and in every place too.

Mr. Barwick: Was that pipe central with the inlet of the fan?

Professor Carpenter: The position of the pipe is pretty well shown on page 111, diagram 2. There is a very good drawing of the fan. The outlet pipe was a square pipe without a chamber, in this case extended, and the measurements were made about 12 or 15 feet from the fan. The inlet was on one side only.

Mr. Kent: Mr. President, there are a few questions I would like to ask about this subject. On the last page of the paper it is stated that the capacity is equal to the cube of the diameter, multiplied by the number of revolutions and by 0.555. I would like Professor Carpenter to put that formula in some other form, so that the breadth may be a factor in the computation.

Professor Carpenter: In the paper presented at the Saratoga meeting that formula was discussed and it is explained how it was obtained, and the breadth comes into that discussion. But it is only eliminated when the fans are made so that the breadth is a certain proportion of the diameter in every case.

Mr. Kent: The fans may be changed next year and have tapered blades of different diameters and widths. Do you take in tapered blades too?

Professor Carpenter: The formula in its theoretical form would include everything, but the coefficients would vary doubtless with each construction.

Mr. Kent: As to the last formula on that page, that is simply a formula for pressure with free outlet?

Professor Carpenter: In the brackets is the maximum pressure which can be produced.

Mr. Kent: Another point I want to make is as to the conclusion on page 126. I would like him to explain how he accounts for it:

"The effect of change of pressure of the steam which is used in the steam coils increases the total amount of heat given off, but does not increase the heat transfer in proportion to the increase in temperature of the steam"—what follows is what I object to—"and hence it is not advisable to use, for the purposes of hot-blast heating, steam of any greater pressure than that necessary to insure circulation through the coils."

It seems to me that if the steam transfer is greater with higher pressures, as it must be, all other things being equal, it will be simply a question of how far we can go in increasing the pressure without getting too great cost. There will be a minimum, but it will not be as low as the professor said. That would carry us away down below the atmosphere. I don't think the professor himself would install a system of that kind. It would involve too great an expense for heating surface.

There is another point—the transfer of heat per degree of difference per hour decreased with the increase of temperature. I would like to know if the professor has any theoretical explanation of that. I refer to the diagram on page 124.

Professor Carpenter: This paper has brought out a very interesting fact and one which I have pondered over a great deal, and I have been able to arrive at no explanation. Many tests

were made at different times and by different observers, and all of them would substantiate that conclusion; that is, in other words, that the heat transfer did not increase as rapidly as the temperature of the steam would warrant us to expect, and as we had no exception whatever in our experiments, we conclude the results as stated are correct.

Mr. Kent: You haven't got the theory yet?

Professor Carpenter: I simply present the facts as they are, and possibly Mr. Kent may find the theory.

Mr. Kent: There are two different points in the question; one is in relation to the fact that the transfer of heat is less per degree of temperature. That is a matter of fact without a theoretical explanation. The other is a conclusion from a stated fact, on page 126.

Professor Carpenter: I think from those facts you could not draw any other conclusion.

Mr. Kent: Would you advise that we should use steam only of sufficient pressure to insure circulation in the coils?

Professor Carpenter: You are carrying the pressure down to limits which are beyond the limits of our experiments. But I really do not know what I should do under those circumstances. I should certainly feel that a pressure of 2 or 3 pounds was preferable to 50 pounds.

Mr. Kent: I think if I was installing a blower system on a large scale I would carefully consider, for high pressures, whether steam at 250 degrees should not be used instead of bringing it down to 212 degrees or 250 degrees. The price of boilers up to 125 pounds pressure is about constant. Above that you begin to get extras. But why shouldn't we reduce steam pressure to 125 pounds?

Professor Carpenter: If you go into the market and buy a commercial blower, then I might agree with you. But, on the other hand, if you look at it as I looked at it at the time of writing this, that it was a question between a high-priced steam-power boiler or a lower-priced steam-heating boiler—the case is in favor of the low pressure in the coils.

Mr. Kent: In large plants we are using regular water tube boilers of standard form for heating.

Professor Carpenter: That is quite true. I will admit that to be a phase of the question which I did not consider, and taking

that into consideration it is quite possible that I might draw another conclusion.

Professor Kinealy: Don't you think that if you use steam at high pressure you would have more condensation in the mains and in all your pipes leading to your heater than you would at low pressure? If you get better results with low pressure in the heater and there is less condensation in your mains and pipes from your boiler to your heater, it seems to me it would point to using steam of low pressure. How low would depend upon the difference in the size of the heater and the amount of condensation. You have less loss in getting your steam from your boiler to the coil at high pressure than at low pressure, and the low pressure is more efficient in the coil. It is a question of finding that pressure which will give the best service, everything counted—interest on first cost, loss in steam passing from the boiler to the main.

Mr. Cary: I would like to ask Professor Carpenter if, in using the higher pressures, he was able to hold the steam in his trap; in other words, prevent the driving of high-pressure steam through the trap and escaping, not as condensed water, but as steam; if the steam would be held in the coils until it had all been condensed into water, would the fact be as the professor has stated?

Professor Carpenter: If that thing had happened the results would have shown very much the other way, because we determined the heat which was transmitted by the measure of the condensation. Now if the steam had blown through, of course we should have had a great deal more of it; but it did not blow through.

Mr. Cary: As I understood from that the trap is somewhat similar to a bucket trap.

Professor Carpenter: It was a heavily built trap and it stood all right.

Mr. Cary: As I remember, you passed your steam from your trap through a certain amount of water and condensed that thoroughly. You took that precaution after passing it through the trap. Now, with the high-pressure steam you probably would blow through more steam and that would probably be condensed beyond that point, and it would make a showing as is shown here.

Professor Carpenter: I should have explained that although we used the trap, we also had a trap, which was not automatic, ahead of that. In other words, we held the discharged water at a constant level by a water gauge glass in advance of the trap, and we regulated by the gauge everything that passed that, so we never let the water level vary from that point at any time during the experiments. So that really the trap did not cut any very great figure.

Mr. Kent: I suppose you cooled that water too?

Professor Carpenter: We cooled it after it went through the trap.

Mr. Herbert A. Joslin: I would like to ask the professor what provision he made for getting the air out, whether he used any automatic air valve or anything of that sort?

Professor Carpenter: That is a very good question. I will tell you what we did do. Before starting each set of experiments, in order to get an observation, we made two hours' run and took observations ten minutes apart, which gave us twelve readings for every observation. At the beginning, just before we started, we put on the steam and allowed the coils to get thoroughly hot. Then we had a lot of air valves, one in every coil, and those we opened.

Mr. Joslin: Then you made no provision for getting the air thrown off by the condensing steam?

Professor Carpenter: No. I thought it was hardly fair to do anything better than what was done. I always felt a little guilty in doing as well, because I actually believe that we gave the heater a condition rather more favorable than that met with in ordinary practice. Still we did everything we could to get the air out before we started and our results were usually very harmonious as a rule. You can see from the curves, that ordinarily they came pretty well on the curve.

Mr. Jellett: I am glad to see that the conclusions of Professor Carpenter's paper carry out the results that most of us have obtained in properly designed work of this character. Professor Carpenter draws a conclusion here that a heater should have from 12 to 20 pipes in depth. I think I stated in the discussion here some two years ago that it had been my custom, as the result of observation, but not tests, such as the professor has made, that to bring air to the required temperature, to maintain

a room at 70 degrees in zero weather, it was necesary that the air should come in contact with 20 pipes in depth, but that I always built a heater of six sections, four pipes each, which gave one extra section to come and go on in case of accident. I see, in noting the conditions here, that Professor Carpenter has practically found the result of his tests carry out good practice.

I note another point. Referring to Mr. Kent's question as to the difference of temperature of steam you must have two things to get maximum results. First, you must have the area in and around the pipes to equal or exceed by a reasonable amount the inlet capacity of the fan. If you do not have that you do not get your best results, and whether you carry one pound of steam or one hundred you must bring air in contact with a certain number of pipes at the velocity at which it is travelling, in order to get the temperature that you wish to maintain. I have tried it with varying degrees of temperature and you cannot get the result on sixteen pipes with fifty pounds as you can get with twenty pipes with one pound. As contractors are required to guarantee results, it is results we must figure for, not theories. Now, Professor Carpenter's tests show on that point that you can very greatly increase the velocity of your air without making any material fall in the temperature of the air. The increase in the velocity or the amount of air given off is very large, proportionately, to the fall in temperature. Therefore the limit of the capacity of your fan heater has not yet been determined.

A number of years ago I was looking after the installation of a heating system. I met the foreman of construction of one of the blower companies. He was not a theoretical man at all. He never had any special training, but he had been a close observer of the work he had been putting up. I asked him the question what was the measured capacity of a fan heater. He said, given a sufficient area through the heater to equal the capacity of the fan inlet and given the depth of coil necessary to bring the temperature of the air to the desired point, the only measure of the capacity of the fan was the ability of the return pipe to carry the return condensation. He said, "I have never yet found the limit of a properly designed fan heater." I said, "That is rather startling." He said, "I have taken heaters with a velocity of a thousand feet per minute passing through them and I have increased that velocity to four thousand feet and I have maintained

the temperature of the air within ten or twelve degrees, at four thousand, that I have had at one thousand; but I have finally been compelled to stop because the return pipes of the heating system to which my coil discharged were not sufficient to carry my water of condensation." He said, "I have arrived at that simply from practical tests of putting up apparatus. I have put in plants to heat a certain building and they built an extension to it and I increased the speed of my fan and heated the extension without anything more than increased power applied to the blower and increased steam to the heater, the apparatus remaining the same." I thought at the time that he was very wide of the mark, but he was not as far wide of the mark as I thought he was. The results of these careful tests show that you can very largely increase your volume and velocities and at the same time do it with comparatively small decrease in temperature, and I am satisfied that the results of those tests of Professor Carpenter's will show that steam at or close to the atmosphere in a fan heater, assuming that you have got depth of coil enough to bring air in contact and area sufficient to feed your fan without any unusual friction, that you have got the most economical fan heater that you can devise. I am not an advocate of high pressure steam in a heater of this kind. I do not think you get equivalent returns from its use.

Mr. Henry C. Meyer, Jr.: I would like to raise the question as to what is considered good practice in regard to the mean velocity of air passing through hot-blast coils. We all know that there is a difference in the arrangement of the pipes of the different coils, and Mr. Jellett has made the statement that it was his practice, I believe, to make the net area of the opening between these pipes considerably larger than the inlet of the fan. I would like to have some definite information as to just how much greater that must be. In other words, what should be the mean velocity of air passing through the different coils? I believe some people figure it in that way.

Professor Carpenter: I presume the question could be answered a good deal better by some person other than myself. I happen to know what some of the people do use in connection with this work, and possibly what most of the people use, although I am not so certain as to just how extensive the practice is. But we know that the common fan speed of the tips of the

fan is just about a mile a minute. You can count your delivered air under the condition of pressure which exists in these systems as usually about two-thirds of that of the tip of the fan, and that amount divided by the area in square feet of the inlet will give you the velocity.

Mr. Henry C. Meyer, Jr.: Perhaps I did not make myself sufficiently clear. What I want to know is, suppose we have a fan of a certain size, delivering a certain amount of air through a duct of given dimensions, how many pipes wide and how high must those pipes in the hot-blast coils be, in order to give the temperatures that are common in hot-blast practice, making them twenty to twenty-four pipes as mentioned by Mr. Jellett. In other words, how long must the pipes of those coils be and the end openings between the pipes?

Mr. Jellett: It is quite common practice to have one and one-half times the area through the heater of the inlet of the blower. You can possibly get along with a little less, but one and a half times the net area will give good results. Then the question of velocity, of course that varies with the class of work you are doing. In a factory system you will run your blowers at a higher speed, because the humming sound due to the velocity of the air is not objectionable. Take an average hospital system where you are working full velocities of air, it is rare that you will find a blower large enough to pull air through the main duct at a velocity of 2,400 or 2,500 feet a minute. It is simply on account of enlarging the main ducts and flues and having the volume of air move slowly. Assume 2,400 through your blower, the velocity through your heater will be approximately 1,600.

Professor Kinealy: I want first to say something in regard to Mr. Meyer's question. Of course the velocity through the heater is going to depend upon the friction in the ducts after it goes through the heater, and the rule, as Mr. Jellett stated, to make the area through the heater one and a half the delivery area —I thought it was between one and a half and two, and nearer two than one and a half—gives a velocity about one-half that of the tips of the blades. Reducing the velocity to half the velocity of the tips of the fan leaves a larger pressure to overcome friction, friction through the pipes, friction through the ducts and the branches. It may be necessary, it seems to me, in some cases, to make the velocity through the pipes even less than half

the velocity of the tips of the fan, because if you have very long ducts and if they are small so that you have to maintain a high velocity in them, you are going to have more friction there, and therefore you want less friction in the pipes themselves. That means a low velocity.

Now in regard to the paper, it seems to me that it is full of meat, more than we can digest in a short time. I have gone over the paper very carefully, but there are many things here that I do not yet understand. For instance, beginning with the figure shown on page 115, I note that there are there eight sections. The paper does not state whether, when four sections were used, for instance, there was any change in the other sections, other than simply cutting them out. I take it for granted, however, that the friction through the heater was the same in all cases. The construction of the heater shows that it was rather difficult to get circulation through the central portion on account of the number of bends. You could tell what amount the heater was heated by putting your hand on it. I am referring to Fig. 5. Take, for instance, the inner pipe, the section that is shown there, it runs up for a short distance, then there is an elbow that turns to the right, then there is an elbow that runs to the left. There is another elbow runs back to the right, a series of return bends which it seemed to me would make it difficult to make circulation in there unless there was some means to take out, as one gentleman suggested, the air in that part. It is rather queer that the calibration curve for the small anemometer, which I judge is one of the Combes type from the diagram, should be different from the calibration curve for the larger anemometer, which I judge is one of the Biram type.

Professor Carpenter: No; they were both the same, both Caswell.

Professor Kinealy: The diagram shown in Fig. 6 shows the relation between the reading of the anemometer and the actual velocity, while the diagram shown in Fig. 7 shows the relation between the reading of the anemometer, the recorded velocity in feet per minute, and the correction to be added. If we had both diagrams plotted in the same way it would have been easier to compare them. The anemometer whose calibration curve is shown in Fig. 6, you will notice would not move for velocities less than about 30 feet per minute, but it would move for a ve-

locity of about 30 feet. That is a pretty low velocity at which to get an anemometer to move. I have made tests where I found anemometers in good shape, just from the shop, would run at 40 feet per minute. Professor Carpenter, in his paper yesterday, gave an equation showing the relation between the reading of the anemometer and the velocity of the air. The equation, if I remember right, was

$$v = a + br$$

" r " being the reading. I have worked out since I have been in the room here an equation for the calibration curve in Fig. 6. I have only done it roughly and it is about this:

$$v = 30 + \frac{54}{100} r$$

I think that is about right, although there may be some error in arithmetic. The tests that I have made show that the coefficient of r ought to be in the neighborhood of 1, and V ought to be about 50 plus the reading of the anemometer. As to the amounts of air that passed through the heater for the different tests, I note that the fan for the first fifteen tests was running at almost a constant speed, 400 to 404 revolutions per minute, a variation of one per cent. That would mean that the amount of air which would pass through the heater should also be about constant. I note that in our test, the number of cubic feet of air passing through the heater per hour is 882,000, this is shown on page 124. That, I believe, is the greatest amount. Now the smallest amount is 736,000 cubic feet. I think it is in test 12. 736,000 from 882,000 gives you the range of error in the observations which I was getting at. There is a difference of something like 50,000, and 50,000 in 800,000 makes a range of error of only six per cent. That is extremely close work, six per cent. from the maximum to the minimum. The diagram in Fig. 8 showing the variation in velocity is interesting, but it would have been more interesting if we could have had shown on the same diagram the velocity found at the different sections. There is nothing in the paper to show the number of the test when these velocities were measured, but I note that the fan was running at 550 revolutions per minute and the temperature when discharged was 150 degrees. That corresponds to Test No. 16.

Professor Carpenter: I do not think that that test is on here at all. That was merely a diagram taken from previous tests when the air was not heated at all.

Professor Kinealy: What I was getting at was this: It would be of great value to us if from these tests we could determine even for this fan alone a point at which we could hold a Pitot tube, or an anemometer, and get the average velocity of the air through that opening. I find that in test 16 the average velocity is 4,210 feet per minute. That would seem that we were holding the anemometer somewhere down in the lower part of the opening a little bit to the right of the central line, but we have not velocities here and cannot find them.

Professor Carpenter: I can easily supply that information if it is thought worth while, because we have diagrams for every one of these tests, and also all the data you refer to, but the tests which I put in here are merely selected as an illustration showing this variation. The diagram belongs to one of the tests made with cold air before the heater was put in use.

Professor Kinealy: I think it is important for this reason: Hydraulic engineers when they desire to measure the velocity of water pasing through a pipe put a Pitot tube at a certain point, a certain distance between the centre and the circumference of the tube. That has been determined, the point at which you will get the average velocity. That means you have only to make one reading. Now, if we can determine the same point for air flowing through a pipe, or flowing from the orifice of a fan, it simply means, instead of taking a lot of readings which are taken here, we have only to hold our anemometer at one point and take one reading, and we have approximately, at least, the average velocity of the fan, but save a great deal of time. The formula for the heat transmitted, or rather the rule to determine the heat transmitted for various velocities, I take it—it is given on page 123—applies only to these particular tests. That is so, isn't it, Professor Carpenter?

Professor Carpenter: Certainly.

Professor Kinealy: You have taken into account no other tests at all?

Professor Carpenter: It is simply an average.

Professor Kinealy: Diagram 13 is very interesting for many reasons. Several years ago I was asked to predict what would

be the temperature of the air leaving a heater if the pressure were raised from a certain point to a certain other point. Well, Rankine gives a curve, or rather an equation for doing that. I compared Rankine's equation with the results of all the tests I could get, and found it was away off. I then plotted them and got a curve of my own, from which I made the calculation and the curve agrees pretty well with the curve shown in diagram 13. But of more interest than any other is the diagram in Fig. 15. It seems to me that this offers more food for thought than any other part of the paper. The tests all agree, except where five sections were used. In the others the curves are similar and correspond with one another. Now, of course, the curves are too short to warrant us in continuing them to the left to see what would happen if we reduced the pressure to atmospheric pressure, or below atmospheric pressure as has been suggested. The lower temperature is about 245. It would hardly be right to continue the curves even to 220. The range of the tests is rather small, but they point out something upon which we ought to have further experiments. If, as this paper shows, and as is the commonly accepted opinion of those who have put up heating plants, it is better to circulate the steam at a low pressure, we ought to know that, and how much better we ought to know it in order that we may properly design the plants.

Mr. Kent: I will ask, in respect to the same diagram on page 123, that Professor Carpenter will say where the loss would be if there was no velocity of air; isn't it about 2.8?

Professor Carpenter: Yes.

Mr. Kent: So that the height of that above the 3 line represents the increased efficiency due to the velocity of air passing through?

Professor Carpenter: Yes.

Mr. Kent: Mr. Jellett says if you increase the velocity very much more you would have these curves still higher up.

Professor Carpenter: Surely.

Mr. Kent: It would be very good if we could get the diagram extended forward as well as horizontally.

Professor Carpenter: I was very much disappointed in some respects with the outfit we had. We could not, for instance, get velocities any higher than shown. That was the absolute limit of the power in the engine. Hence it was the best we could do.

Referring to Professor Kinealy's question regarding the variation in different parts of the flue, I might say we made some experiments to determine average velocity readings and average temperature readings in the flue, and in the paper which I read on the testing of the heating and ventilating plant in the New York State Veterinary College are given the observations which were made to determine the variation of temperature in a flue, although at the same time we made observations to determine the velocity. The rule that we deduced from that determination, which held true in that particular place both for velocity and for temperature, was this: The average temperature and the average velocity was found at a point about one-third distant from the bottom; we also found a similar point at one-fifth the distance downward from the top and to the right or left of a centre line, a distance equal to one-twelfth the breadth of the pipe. That is, we could take a centre line up or down and go one-twelfth of the diameter of the pipe either side, and we found the average readings at either one-fifth the distance, reckoned from the top, or one-third the distance, reckoned from the bottom, and in the centre; in other places the results varied considerably from those.

Professor Kinealy: Well, that is a great point to know that. Take one reading in the air pipe, and you have got the average velocity.

Mr. Cary: I would like to ask Professor Carpenter if any flues were extended beyond the heater and readings of the loss of pressure had and the friction through the heater?

Professor Carpenter: The flue in which this work was carried on was extended to some little distance, 15 or 20 feet, and there we had the ordinary back-pressure gauge, but we only took readings a distance of about twelve feet. In fact it would require an extremely long pipe to make a measurement which would be at all accurate to determine the friction losses. They are exceedingly small and would require a good deal finer method of testing than available at the time of making these tests.

Mr. Cary: There is one other question. In the conclusion it is said: "The effect of increasing the velocity of the air increases its capacity to take up heat an amount which increases at a greater rate than the square root of the increase of velocity."

This would tend to make some users of fans increase the speeds of their fans, and at certain places the increase of vibration and noise would make a great deal of trouble, and then by increasing the speed of your fan you increase the amount of power required materially. So would Professor Carpenter recommend in certain places the putting in of a larger fan than the entrance to the heating coils and reducing its area so as to get the increased velocity? That would be the natural way of getting at that by keeping a lower speed of your fan and without increasing the power materially required to drive it.

Professor Carpenter: That question I think has already been before us in a little different form. I think in the first place it is the common practice now among all builders to put in fans considerably larger in diameter than the distance across the heating surfaces, but I do not think it is the practice of any builder to run his fan with peripheral speed less than a mile a minute. I am quite fully convinced in my own mind that it would be economy to run it up to about six thousand feet per minute, and I feel also certain that we could do it without making noise or making vibration. The noise is invariably due to the casing, and if the form of the casing is proper and at the proper distance from the fan the noise can be practically all reduced. As to the fact that it takes more power, that is true; but at the same time the fan will deliver more atmospheric air per horse-power, with a back pressure of about an ounce, than with a less pressure. Of course it will not deliver more compressed air, but it will deliver more atmospheric air. All the tests, both those that we have made and the foreign tests, point to that, that the fan efficiency is higher at about that pressure than with lower pressure.

Mr. Kent: And that corresponds to about six thousand feet a minute.

Professor Carpenter: I think it does.

Mr. Paul: There is one point that has not been brought up that it really seems to me should be looked at, and that is the point mentioned in the paper that with one or two or three sections a large amount of steam is condensed per square foot, which would mean a large amount of water that would have to be taken away from each section, and in our experience in going over a large number of plants we have found no change has been made in the heater to supply steam in larger quantities to the

first section where we raised the temperatures of the cold air. That means that the pressure cannot be maintained in the first section on account of the condensation being so much greater in that first section, and by careful experiments we have found that it was absolutely necessary to increase the amount of openings, to let steam into the heater on the first section, the section that received the cold air and had a large condensation. Of course, at the same time when you reduce the pressure on the first section you prevent the water from flowing out, because the pressure on the other sections will back the water up. I think that is a point that we could make some careful study on and receive a good deal of benefit.

Mr. Barwick: That point is well taken, Mr. President. I have witnessed drying work in which the first cylinder in the dryer has taken considerable steam, in fact in a proportion equalling about eight times more than most of the other cylinders. Oftentimes the first cylinder will run to a vacuum and we have placed a connection from the cylinder down thirty feet so as to clear that cylinder of water and maintain the cylinder as free as possible while the other portions of the drying machine were in operation. It is the same with a hot-blast heater, the first section receives the cold air, and will condense considerably more than those that are in the casing farther along. That is shown by the single section in the test given by Professor Carpenter. It would be a wise thing to take the first section independent of the other sections. I think that you would get better results from it under those conditions.

Mr. Paul: I want to say this, if we are going to put a check on it we have got to put it on low enough, so as to get water enough to overcome the difference.

LXXV.

THE REMOVAL OF DUST FROM BOILER ROOMS.

BY ALBERT A. CARY.

(Member of the Society.)

In the Atlantic States, oil-burning under boilers has become too expensive a luxury to be much indulged in, and, although one can find an occasional oil-burning plant to-day, the old installations are fast disappearing, and coal is being substituted for oil, followed by a material saving in the cost of fuel.

During the past year a manufacturing concern in New Jersey consulted me about making a change of this kind, and the problem was somewhat complicated with a demand that the new plant should be as non-productive of dust as the oil-burning plant had been. They informed me that the principal reason why oil had been adopted originally was because of its freedom from dust.

This concern manufactures a rubber-covered insulated wire, and those acquainted with the manipulation of rubber will recall that it is kept in a gummy or sticky plastic state during its entire process of manipulation, and, therefore, any dust will stick to it tenaciously, and such foreign matter will affect its power of insulation appreciably; therefore in this factory every source of dust is done away with as much as possible.

The factory is long and comparatively narrow, with a wing running back from each end, thus forming a sort of square U, and having a square courtyard in the centre (with buildings on three sides of the square). In about the centre of this court the boiler house is placed, thus giving any ash or dust coming from it an excellent opportunity to enter the many windows of the factory which surrounds it.

When oil is used, perfect cleanliness (so far as dust is concerned) is possible, but when coal is substituted, dust will arise from every shovelful of coal that is fired, and afterwards the dust from the ash and refuse, when fires are cleaned, will scatter

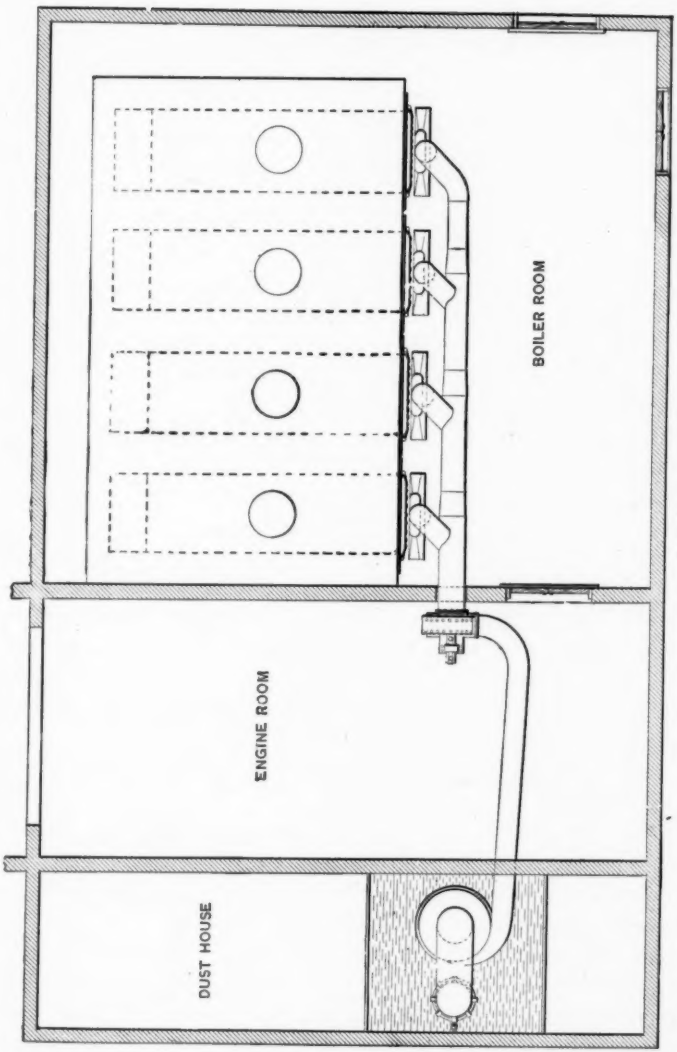


Fig. 1

itself everywhere. The avoidance of such trouble was a problem to be solved.

A number of schemes presented themselves to my mind. The placing of screens in the factory windows interfered materially with the free ventilation of the various rooms, this being very essential in a rubber factory.

Another scheme included a dust house adjoining the boiler room, into which the dust-laden air might be blown and filtered to the outside air, through wire and cloth screens; but I condemned this on account of its merely transferring the trouble from one place to another close by, and, perhaps, aggravating the trouble when the screens were taken out and cleaned periodically.

I finally devised a method which seemed to meet all objections.

By referring to Fig. 1 it will be seen that the steam plant has its boiler room and engine room adjoining.

The boiler room contains four horizontal tubular boilers, 66 inches in diameter, and 18 feet long, with 80 three-inch tubes, having a nominal rating of 100 horse-power each. The smoke flues are connected to the rear of these boilers.

I have provided a dust house next to the engine room, but on the opposite side from the boiler room. This dust house is designed so as to receive another 100 horse-power boiler, which will doubtless be required as the demand for steam increases. Surrounding conditions made it impossible to erect this house at the opposite end of the boiler room, where it would otherwise have been placed.

Figs. 1, 2, and 3 show the general arrangement of ducts, exhaust fan, etc.

It will be seen (in Figs. 2 and 3) that the four suction ends of the ducts terminate in comparatively narrow open mouths, extending almost across the entire width of the boiler front, and they are placed directly above the firing doors.

All coal is brought into the boiler room on an industrial railway in Hunt's charging cars, made for this purpose, each car carrying one ton. These cars are filled from a distant coal pocket, and are then pushed by one man in front of any boiler which may need coal. The side of the car is then dropped like a hinged shelf, and coal is shovelled direct from the car into the furnace. As the car is easily moved from one boiler to another.

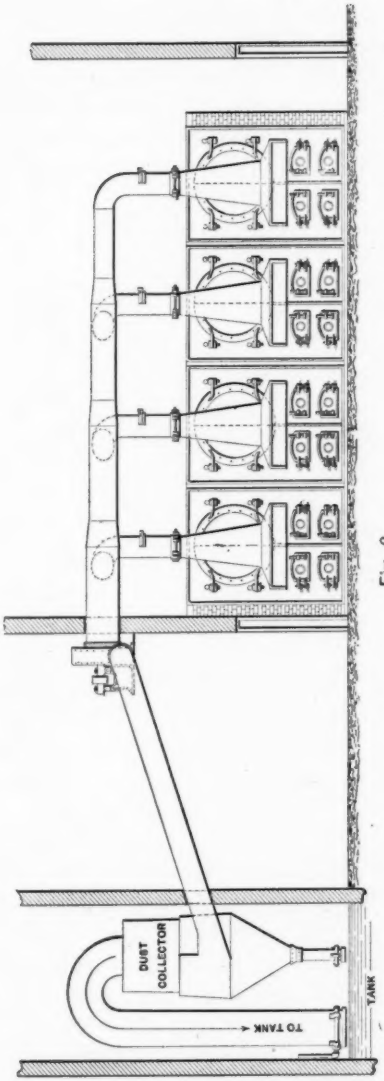


Fig. 2

no loose coal is dumped on the boiler-room floor. It will now be seen that any dust rising from the shovelled coal will be drawn into the suction mouth of the exhaust duct, since the shovelling operations take place only in front of these mouths.

When the boiler furnace is being cleaned, any dust accompanying the ash and clinker, as they are pulled out of the firing door, is drawn directly into the suction mouths, and this is again

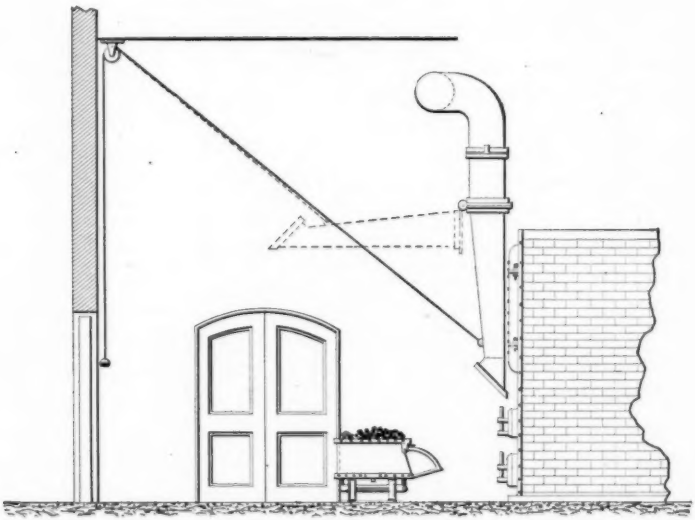


Fig. 3

the case when this refuse is shovelled from the floor into an empty charging car to be taken out of the boiler room.

Before following this dust out of the boiler room, I would call attention to the construction of the vertical suction pipes above the firing doors. These pipes, it will be seen, are directly in front of the upper cleaning doors of the boilers. In order to open these doors, when the tubes require cleaning, a hinged joint is provided in the suction pipe, as shown in Fig. 3, and the lower end of the duct is thereby raised out of the way.

Following the dust after it enters the ducts, it is discharged by the Sturtevant steel-plate exhauster (placed in the engine room) into a centrifugal dust collector placed in the dust house.

The heavier particles are then discharged through the bottom

pipe of this collector, and, as a further precaution, to catch any light floating particles which may escape through the upper or air delivery end of the collector, a pipe is run from this top opening, and, bending downwards, terminates within two inches of the surface of water held in a tank placed below the level of the floor in the dust house. The bottom-discharge pipe from the dust collector also terminates similarly, and thus all the dust, etc., is projected upon the surface of the water, where, as it gradually becomes soaked, it sinks to the bottom of the tank, from which

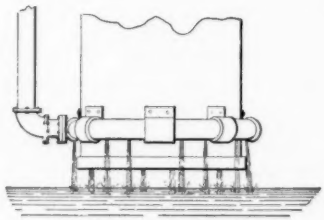


Fig. 4

it can be either washed out with a hose and stream of water, or else be shovelled out as a mud.

In order to further catch any particles of dust which might otherwise escape, a one-inch water pipe is bent to a circle and secured concentrically around the lower ends of each of these delivery pipes, as shown in Fig. 4. The lower sides of these pipe rings are perforated with 1/8-inch holes so as to produce a constant shower of water around the outlets.

This arrangement leaves a free escape of air, essential for best results with the type of fan used.

A sewer connection near the top of the tank keeps the water at a constant level, and the added water from the sprays thus has a tendency to float off a considerable amount of the lighter floating particles before they have time to sink.

DISCUSSION.

Mr. Henry C. Meyer, Jr.: It may add to the value of this paper if I described briefly a method which was used to remove ashes from the gases discharged from a boiler. In the Fifty-ninth Street Station of the New York Steam Company, where

they burn very fine anthracite coal, they had much trouble from particles of white ash that escaped from the chimney and did a great deal of damage in the residences in the neighborhood. I believe the difficulty was finally overcome by installing an induced draught plant which was fitted with economizers and a smoke-washing device in which a perforated pipe was carried across the smoke flue, discharging water in a sheet through the current of waste gases. That water was afterwards, I think, used to feed the boilers. Whether or not they ever had any trouble from that I don't know. But the apparatus seemed to be successful in curing the difficulty.

Mr. Kent: I was present at a test of the plant that Mr. Meyer speaks of, and made some of the tests to determine whether there was any dust coming out of the chimney. I held my derby hat over the chimney for a long time, five or ten minutes or so, and found it covered with particles of water, but not a speck of dust. Then we took some black tar and put it on a board and held it over the chimney for fifteen minutes and could not detect the slightest evidence of dust. It seemed a perfect solution of the question.

Mr. Cary: I proposed that a number of freshly painted boards be placed around the different windows and tacked against the sides at different points and they would very soon show the amount of dust that would be collected, and that was the method that I proposed for testing the efficiency of the plant described in the paper.

Mr. Gormly: It would seem to me, Mr. President, that Mr. Cary may run into trouble in a climate like ours where the temperature falls so low, and if this plant is not running constantly the water may freeze. That is, if the plant is shut down over night, when he starts up in the morning he may find the water frozen in the tank where he throws the dust. I should think it would be advisable, if it is not located in a warm place, to have a coil put in there with a circulation of some warm medium, such as steam or hot water, to prevent freezing, because if the water should freeze he would naturally have trouble. I suppose while the plant is running there is sufficient heat picked up at the mouth of the furnace to prevent freezing, and yet it is a thing that may bring trouble in future if he does not look after it.

Mr. Cary: In answer to Mr. Gormly's remarks I would say that this plant has been running for a number of years, sixteen or eighteen hours a day, and steam is left on all night to supply vulcanizers, in which the material is left, so that this plant will be in operation during the whole twenty-four hours during the whole three hundred and sixty-five days of the year. That is a point I thought of. But the amount of hot air taken from the boiler-room undoubtedly would be sufficient to prevent any freezing. I believe Mr. Jellett has had experience in suppressing the dust nuisance.

Mr. Jellett: I have had no experience in taking dust from boiler rooms, but have had experience in removing dust from all sorts of places. On the general question of removal of dust, I have had a good deal of experience. The latest was in the Saw Works of the Disston Manufacturing Company at Philadelphia. They have a number of emery wheels where they grind the faces of the saws. They used oil in connection with the emery on the large wheels, and the material would collect and at times it would be thrown out into the faces of the men and be exceedingly disagreeable. At the same time the emery dust must be saved, as it is valuable. One trouble that we ran across at starting was that the material was inflammable. Emery dust with oil produces spontaneous combustion under certain conditions. They had a vacant building on the property some 100 feet or more away from the main building in which the grinding rooms were located. It was a two-story building, approximately about 30 feet square; I had all the windows built up, leaving four brick walls, and a brick-paved floor, and we put a metal roof over it. In the centre we placed a large ventilator, some six feet in diameter, to allow for the escape of air from the various blowers that were exhausting from the saw grinders. I increased the area of discharge to exceed slightly the fan discharge and put all the pipes on a down grade towards the dust house. We were not allowed to use water to settle the dust, because water produced spontaneous combustion and ruined material for future use. We expanded the air in this dust-room and put in a series of baffle-plates and then finally a plate below the outgoing ventilator. This reduced the velocity very materially in the dust house. We have been enabled by this system to get back about 95 per cent. of the dust that is picked up. A small amount still goes out—

you can see the color, but there is practically no deposit. That is, it is so light that the air carries it up. It does not even deposit on the roof of the building. We could overcome this entirely, I think, if we used a centrifugal dust separator. But the owners did not want to go to that expense in this building, as they have to go in and clean material every once in a while, and if a fire takes place the solder of the centrifugal would be promptly melted and the centrifugal would go to pieces. I have known fires to occur in that house twice a day under damp conditions of weather. The ducts themselves become pretty hot, because the saws are hot, and we have to be very particular that a fire in the building would do no particular damage. They simply let it burn itself out, and do not bother with it.

I had a case some time ago in a large machine manufacturing concern at Philadelphia, where the soft coal smoke from the blacksmith shop floated into the drawing-room windows and caused a great deal of damage to the drawings. There we put up a system of ducts and a blower, adjustable hoods over the forges and fires, so that when the fire was being blown up the hood was dropped when the men were working. There are automatic weights on it. It is counter-balanced so nearly that the hood will rise with slight effort. This has prevented the entire trouble. The air is discharged into a centrifugal dust separator and deposited in a bin. There has never been any trouble since. No water is used; it is simply by the action of the centrifugal which is specially built with enlarged inlets. One difficulty we found there when we started was that the gases ruined the galvanized iron, ate it out very quickly. After two years' use it was practically destroyed. When the ducts were renewed we built them of special leaded iron, and there was no further trouble in that direction, and the separator itself was built of the same metal. I found one case some years ago of a removal of dust that I was unable to overcome. It was in printing-ink works. It was lamp-black. We tried wet curtains and dust-rooms. We tried all sorts of ways of expanding the air and reducing its velocity, passing through screens. It had some effect, but it did not fully correct the trouble. We finally blew it a foot under water in a tank, and the dust came up in bubbles through that water, like the so-called blind man's buff that you find in country fields. It will come up with a bubble, with a

skin over it, and reach the outer air and burst and throw out the dry dust. It was the most peculiar thing I ever saw. The reason for the experiment was that the people of the neighborhood had complained and had applied for an injunction. This material would float in the air two blocks from the factory until the dirt dried out and somebody's washed clothes would get the benefit of it, and finally the proprietor had to take that department of his works out of the town. All the known methods of settling dust were inefficient in that case. I have been successful in settling bone-black dust in sugar refineries, but the same method applied to the lamp-black dust did not work.

Mr. Cary: This paper was presented with hopes that it would bring out a considerable discussion on this subject. There are certainly many places where dust is such a nuisance that owners are willing to pay well for its suppression.

This trouble occurs in some draughting rooms, and also in many plants, such as looking-glass manufactories, where dust must be kept from the glass surfaces or the mirrors will be spoiled. So I hope that we may hear from others who have had experience in this line, as I believe such work comes within the province of the ventilating engineer, and seekers for such information should find what they are looking for in our "Transactions."

Mr. Andrew Harvey: I should like to ask Mr. Cary if he takes ashes out of the ash doors, or if he has an automatic means of doing this?

Mr. Cary: The device shown in this paper is as simple a one as I could devise to fully accomplish the purpose, and, therefore, no attempt was made to remove the ashes in any other than the regular way. The ashes are pulled forward through the front firing or ash-pit doors, and could be shovelled from the dead plates directly into one of the cars, or else could be pulled out so as to drop on the floor in front of the boiler and be shovelled from there into the car. It was impossible to place anything below the surface of the boiler room floor, on acount of water rising very near this level.

Mr. Harvey: I have arranged a number of cases where there were boilers set in that way by just putting a half-round trough at the back, alongside of the bridge wall, and had a worm, and then at the outside of that where it passed away from the boiler a

perfectly tight covered duct, and carried that right outside of the building.

Mr. Cary: I had to go further in this case. Carrying the ashes outside of the building, it would still place them in a position where they would be apt to give trouble, to say nothing about the other sources of dust which would not be cared for. I refer to dust arising from the coal which is being shovelled from the car into the furnaces and also that coming from the ashes during the time the fires are being cleaned.

Mr. Kent: Mr. Cary does not say what becomes of the air after he discharges it two inches above the surface of the water.

Mr. Cary: There is a ventilator placed in the roof through which this air escapes.

Mr. Kent: What is the use of that long dust house there, or is it only made that size to take a boiler?

Mr. Cary: This house was designed to receive another boiler.

Mr. Kent: That marked "dust house" is not necessary?

Mr. Cary: No, sir.

Mr. Henry C. Meyer, Jr.: I should like to ask Mr. Cary if he knows about how much dust was collected. I think it would be quite interesting if he has any information about that.

Mr. Cary: I am sorry to say that I can supply no information at this time on the subject. Perhaps I owe the Society somewhat of an apology for presenting this paper prematurely. This plan has been submitted to my clients and accepted and will doubtless be installed.

Before offering the paper I asked the managers of the Society whether it would be proper to present it, with the idea of obtaining a discussion of the subject, and they told me that it would, so I took the liberty of offering it at this time. Later on I may report further concerning the results obtained.

Mr. Kent: What do you think about discharging that dust under water instead of two inches above the surface?

Mr. Cary: Any one who has experimented with a blacksmith's forge fan, which is practically the same as the one described in this paper, will understand my reason for doing this. The fan, as long as its outlet is not much obstructed, will produce a blast which will give an excellent fire, but by simply covering the outlet lightly with your hand, the discharge blast ceases and

the " paddles " revolve uselessly in their case. In other words, the back pressure on such a fan, such as would be obtained by placing its discharge outlet under water, must be reduced to a small resistance to obtain the best results, both as to working efficiency and power required for operation.

Mr. Barwick: I would like to ask Mr. Cary if he considered passing these under the grates and utilizing the air for feeding his boilers with air—feeding his grates—if that wouldn't be a good way to get rid of it?

Mr. Cary: I considered that, but my clients were so insistent upon entirely ridding themselves of the dust that they wanted to take no chances at all. I thought that blowing this air under the grate bars might send some of the dust along with fine ash up the chimney, from the top of which it might be scattered to the surrounding buildings.

Further, the amount of air necessarily discharged would probably be much in excess of the amount required for perfect combustion, and consequently a considerable waste of fuel would result, to say nothing of the inability of the boiler attendant to regulate his fire to take care of the varying demands for steam.

While Mr. Kent is preparing his drawing I might speak of the dangers attending the use of cheese-cloth and bagging screens. Frequently the dust blown by fans from manufacturing plants is highly inflammable, and spontaneous combustion often starts in such refuse. A short time ago I met a German manufacturer who spoke of several fires which had started in his screen cloths. One fire was due to another fire in the neighborhood, where burning brands were blown into the screen frame, which set the screen on fire, and communicated to his building, resulting in a serious loss. This caused him to do away with the old method of screening his air, and he substituted sheets of canvas set at an angle of forty-five degrees. He kept a sheet of water flowing over this constantly, and he blew the dust-laden air onto the water, which caught the greater part of the dust. This is somewhat novel and may be of interest to some of the members of the Society.

Mr. Abram C. Mott: It might be of interest to members to know that there is an article made which is of very general use in foundries for removing the dust from their cleaning mills, which is very similar to the article recently illustrated. It con-

sists of a large cast-iron, or it might be wrought iron, tank, which is set as near at hand as may be desirable, practically the same as illustrated by the gentleman who recently spoke, with water to wash it and carry it up, man-holes to clean it out. It is a commercial article.

Mr. Kent: I have sketched on the board the most efficient dust collector I have ever seen. You can see it in the oxide of zinc works at Bethlehem, Penn. Oxide of zinc is exceedingly fine powder—absolutely impalpable. It is generated in these furnaces. It is carried along in a large duct and discharged through nozzles into a great number, a hundred or more, of long muslin bags. I am not sure just what the nature of the material is. It may be Canton flannel. These bags are about thirty feet long and two feet in diameter, so they expose an enormous surface. The dust gradually comes into the bags, and as there is a slight pressure behind it, forcing it along, the air expands the bags to a cylindrical shape and comes out of the interstices of the flannel or muslin, or whatever it is, and leaves the oxide of zinc inside. That seems to be an absolutely successful dust collector. One can walk through the building there among these bags and not get dusty.

Mr. Jellett: There is an escape of air through those bags, necessarily, from the pressure of the blower. Some time ago I erected three fans in the bag house of one of the zinc works for the purpose of removing that surplus gas. There were a thousand bags in the house. Instead of packing in barrels, they packed in bags. At the end of every one of those funnels on the different tiers throughout the building they attached a bag. The average temperature of the room on the upper platform was 145 degrees. At times the bags took fire on the upper tier, the air is so hot, and the difficulty in there was that the men nearly choked with the gases, together with the very fine dust that is almost imperceptible, and a fire starts and the men cannot get there quickly enough on account of the thick fumes. We put in three exhaust fans with fan houses on the roof to relieve the surplus heat and gas of that fine dust. While in the room you can see from one end of the bag house to the other and you will hardly notice any particular dust. That is largely accountable for by its color; it is white. If you go up to the roof in front of the fans you will find there is a considerable amount of dust.

This plant was formerly owned by the old Lehigh Zinc Company. It is now the Friedensville Zinc Works. It is the oldest zinc plant I think in this country. This was the experience that I had there. The first intention was to remove the high temperature air and gases. But they found also that they had dust. It came through the bags with the pressure from the fans.

Mr. Kent: The place I was at was in Bethlehem. I remember particularly noticing the strange absence of dust among the bags.

Mr. Jellett: It has such a peculiar whiteness that you can see from one end of the building to the other and you would not know that there was any dust. If you go to the upper tiers of platforms near the ceiling, you will find the deposit of dust there.

LXXVI.

THE RATING OF STEAM AND HOT-WATER BOILERS FOR HEATING PURPOSES.

BY JAMES MACKAY.

(Member of the Society.)

The capacities or power of all boilers, excepting those made solely for heating purposes, are satisfactorily determined according to well-established standards, and boiler makers understand that a given capacity may be developed from certain given dimensions and conditions.

The manufacturers of heating boilers, however, do not determine the capacities of their product with any degree of uniformity. Some rate the capacity higher, others lower, than the grate and heating surface would seem to warrant, and hardly any two agree, even approximately, upon the capacity of boilers that are apparently alike and which should develop about the same power. Many manufacturers make boilers identically alike for both water and steam; yet, there is a wide difference in the proportions which the ratings of the water heaters bear to those of steam.

Perhaps it is just to assume that the commercial ratings, which prevail among makers of heating boilers, are all based upon different conditions, and are therefore made in good faith; but it would be a distinct advantage if the varying conditions were made to harmonize, and standards established upon which to base capacities.

The temperature of water, or the pressure of steam, affects the capacity developed; but perhaps the most important condition is the amount of fuel consumed per square foot of grate per hour. The writer has made some tests and experiments, with a view of ascertaining the value of fuel, the quantity of heat absorbed per square foot of boiler-heating surface, and the amount emitted

per square foot of radiation. The fuel used was a good quality of Pennsylvania anthracite coal; the grates upon which it was consumed averaged 50 per cent. air space; the boiler surfaces were flat, round, vertical, and horizontal, and at angles from thirty to forty-five degrees, the distance of the heating surface from the surface of the fire varying from twenty to forty inches; the course of the heated gases and products of combustion was such as to render as much as possible of the heating surface effective, and to bring them to the chimney at a comparatively low temperature. The radiator was a well-known, two-loop pattern, prime cast-iron surface, thirty-eight inches high, and, as the manufacturer's rating of surface was found to be slightly inaccurate, due allowance for this was made. The conditions under which the tests were conducted were such as are usually met with in ordinary practice, care being taken to avoid and eliminate anything of an unusual nature. Where the radiators were placed, the average temperature maintained was 70 degrees Fahr., the external temperature varying from 10 degrees Fahr., above zero, to zero Fahr., and the conditions of the atmosphere being normal. While the effective thermal value of one pound of good coal was found to be, in many instances, greater than 10,000 B. T. U., it was considered that this was a conservative value. By comparing the weight of coal consumed with the different temperatures of water, fire, and flue, and the weight of the water of condensation at different pressures, the value of boiler surface was determined. The cubic feet of air raised to 70 degrees Fahr., at different temperatures, was ascertained, and from the result the number of heat units emitted by one square foot of radiation was computed. The following table gives the amount of air heated 70 degrees Fahr. by one square foot of radiation, at different temperatures in the steam and water:

Temperature of Steam in Radiators.	Cub. Ft. of Air Raised 70° F. by 1 Sq. Ft. of Radiation.	Temperature of Water in Radiators.	Cub. Ft. of Air Raised 70° F. by 1 Sq. Ft. of Radiation.
212	189	140	79
215	194	150	93
219	201	160	107
222	207	170	121
225	213	180	137
227	217	190	153
230	222	200	169
		210	185

In this connection it is interesting to note that Mr. Kaeuffer, M. E., of Germany, has made the following deductions from careful tests as to the value of radiating surfaces, based, however, upon steam pressures, varying from 10 to 15 lbs.:

Smooth, Vertical, Flat W. I. Surface emits 406 B. T. U. per sq. ft. per hour.
" " Pipe " " " 480 " " " " "
" Horizontal " " " " 369 " " " " "

These results would closely correspond to our practice by reducing the pressure to those used in America.

Mr. A. R. Wolff, M. E., following the same investigation, at a steam pressure of about 2 lbs., gives the following results:

Bronzed C. I. Radiators (American Manufacture), 250 B. T. U. per sq. ft. per hour.
Plain " " (not bronzed) " " 400 " " " " "

and the same radiators emit 60 per cent. of these amounts for hot water.

As the pressure Mr. Wolff gives is somewhat indefinite, the results are valuable only in a general way.

Mr. F. Schumann, C. E., in many valuable tables, gives the heat emitted per square foot of steam and water radiating surface per hour, at different temperatures in B. T. U., based upon the experiments of Peclet. His formulas are made from accurate deductions, and the results compare closely with those of Professor Carpenter, Mr. Baldwin, and other American authorities. Foreign writers, however, although giving us much information as to details, and using practically the same methods of computation, give results that rate boilers much higher than our practice would warrant, this being due to different conditions and requirements.

By measuring the heating surfaces of boilers of several different constructions, representing predominating types, it was found that the total surface averaged about 25 per cent. greater than the effective heat-absorbing surface. The non-effective surface was that upon which the fire and gases did not impinge, such as the bottoms of horizontal flues, the tops of horizontal water tubes, and flat planes, also certain portions of vertical surface, masked from the fire and gases by ribs or connecting bars placed to divert the course of the gases. Insulating the non-effective surface did not affect results, but when even remote effective surface was insulated, the results were diminished.

The average absorbing value of heating surface varied from 2,000 to 2,800 B. T. U. per square foot. By increasing the

temperature of the fire and the quantity of fuel consumed, higher averages were obtained; but in view of the attention required, they could not be termed conservative.

Boilers containing the largest percentage of direct fire surface, approaching 75 per cent. of the total surface as a limit, developed the highest efficiency; but when this limit was exceeded, the chimney temperatures increased, and the operation of the boiler became unsteady, showing that less than 25 to 30 per cent. of flue surface was undesirable.

The results obtained from different proportions of fire and flue surface are here given:

Fire Surface.	Flue Surface.	B. T. U. Absorbed per Sq. Ft. of Heating Surface (Average).
25 to 30%	70 to 75%	2,000
35 to 40%	60 to 65%	2,200
45 to 50%	50 to 55%	2,400
55 to 60%	40 to 45%	2,600
65 to 70%	30 to 35%	2,800

Small boilers contained a lower proportion of fire surface, and sustained a greater loss of heat than large ones, from local radiation; therefore, greater efficiency developed as the size of the boiler was increased.

The ratio of increase was as follows:

Sq. Ft. of Grate.	B. T. U. Absorbed per Sq. Ft. of Heating Surface (Average).
Up to 3½	2,000
" 5½	2,200
" 9	2,400
" 13	2,600
" 20	2,800

This ratio was observed while using the proportions of heating surfaces previously given, and, of course, would vary if the proportions were changed.

But, after all, the fuel is the fountain head, as the quantity consumed practically governs the capacity of a given boiler; that is, up to the absorbing limit of its heating surface. Now, it would seem quite feasible for manufacturers of heating boilers to adopt as standards a certain pressure for steam boilers, and a given temperature for water heaters; then to base ratings upon the thermal value of fuel consumed per square foot of grate, the absorbing value of boiler heating surface, and the heat emitted per square foot of radiation. With these values decided upon, if only approximately, the situation would be much clearer.

The two tables here given are results of tests outlined, and are based upon the following formula:

Let A = effective thermal value of coal.

Let B = B. T. U. emitted per sq. ft. radiation per hour at 70 degrees Fahr.

Let C = lbs. coal burned per sq. ft. of grate per hour.

Let D = B. T. U. absorbed per sq. ft. effective boiler surface per hour (average).

Let X = sq. ft. of radiation per sq. ft. of grate.

Let Y = minimum sq. ft. of effective heating surface per sq. ft. of grate.

$$\text{Then} \qquad X = \frac{AC}{B}$$

$$\text{and} \qquad Y = \frac{AC}{D}.$$

The value of A in this formula is taken here at 10,000 B. T. U., and the different values of the other reference letters are given in the tables below. The quantity of coal consumed per square foot of grate per hour is given in the first column at the left; the next columns give the square feet of radiation per square foot of grate, for different quantities of coal at pressures and temperatures as indicated at the top of the tables, and in the next line below are given the B. T. U. emitted per square foot of radiation per hour at 70 degrees Fahr., for the different temperatures. The minimum square feet of effective heating surface required for different quantities of coal are given in the five columns at the right; and at the bottom of each column is given the B. T. U. (average) absorbed per square foot of surface.

Temperature of Water (Degree)		140	150	160	170	180	190	200	210	Minimum Sq. Ft. Effective Htg. Surface Required per Sq. Ft. Grate.				
B. T. U. Emitted per Sq. Ft. Rad. per Hour at 70° F.		115	135	156	177	199	222	246	270					
		Sq. Ft. Radiation per Sq. Ft. Grate.												
Lbs. Coal per Hour per Sq. Ft. of Grate.	10	869	741	641	565	502	450	406	370	35½	38½	41⅝	45½	50
	9½	826	703	609	536	477	428	386	352	34	36½	39⅝	43½	47½
	9	782	666	577	508	452	405	366	333	32½	34½	37½	41	45
	8½	739	629	545	480	427	383	345	315	30½	32½	35⅜	38⅝	42½
	8	695	592	513	452	402	360	325	296	28½	30½	33⅓	36½	40
	7½	652	555	480	424	377	338	305	278	26½	28⅓	31¼	34	37½
	7	608	518	448	395	351	315	284	259	25	27	29⅝	31⅔	35
	6½	565	481	416	367	326	292	264	240	23½	25	27	29½	32½
	6	522	444	385	339	302	270	244	222	21½	23	25	27½	30
	5½	478	407	353	311	276	248	224	204	19½	21⅓	23	25	27½
	5	435	370	321	282	251	225	203	185	17½	19½	20⅝	22½	25
	4½	391	333	288	254	226	203	183	167	16	17⅓	18½	20½	22½
	4	348	296	256	226	201	180	163	148	14⅜	15⅔	16⅔	18½	20
	3½	304	259	224	198	176	158	142	130	12½	13½	14⅔	16	17½
	3	261	222	192	169	151	135	122	111	10½	11½	12½	13⅔	15
Sq. Ft. Radiation per lb. of Coal.*	....	87	74	64	56.5	50	45	41	37					
		B. T. U. Absorbed per Sq. Ft. Htg. Surface per Hour (Average).....								2,800	2,600	2,400	2,200	2,000

* On the assumption that the coal has an effective thermal value of 10,000 B. T. U. per pound.

Steam Pressure.		Atmosphere.	1 lb.	2 lb.	3 lb.	4 lb.	5 lb.	6 lb.	Minimum Sq. Ft. Effective Htg. Surface Required per Sq. Ft. Grate.				
Temperature, deg. F.		212	215	219	222	225	227	230					
B. T. U. Emitted per Sq. Ft. Rad. per Hour at 70° F.		275	283	293	302	310	316	323					
		Sq. Ft. Radiation p. Sq. Ft. Grate.											
Lbs. Coal per Hour per Sq. Ft. of Grate.	10	363	353	341	331	322	316	309	35⅘	38½	41⅝	45½	50
	9½	345	335	324	314	306	300	294	34	36½	39⅝	43⅓	47½
	9	327	318	307	298	290	285	278	32¼	34⅝	37½	41	45
	8½	309	300	290	281	274	269	263	30½	32⅝	35⅜	38⅝	42½
	8	291	283	273	265	258	253	248	28⅘	30¾	33⅓	36½	40
	7½	272	265	256	248	242	237	232	26¾	28⅝	31⅛	34	37½
	7	254	247	239	231	226	221	216	25	27	29¼	31¾	35
	6½	235	229	222	215	209	205	201	23½	25	27	29½	32½
	6	218	212	205	199	194	190	186	21⅗	23	25	27½	30
	5½	200	194	188	182	177	174	170	19⅝	21⅛	23	25	27½
	5	182	177	171	166	161	158	155	17⅘	19½	20⅝	22⅝	25
	4½	164	159	154	149	145	142	139	16	17⅓	18⅓	20½	22½
	4	145	141	137	132	129	127	124	14⅘	15⅝	16½	18⅛	20
	3½	127	124	119	116	113	111	108	12½	13½	14⅔	16	17½
	3	109	106	102	99	97	95	93	10⅔	11½	12½	13⅞	15
Sq. Ft. Radiation per lb. of Coal.		....	36	35	34	33	32	32	31				
		B. T. U. Absorbed per Sq. Ft. Htg. Surface per Hour (Av.)							2,800	2,600	2,400	2,300	2,000

To illustrate, we will assume a steam boiler contains 3 square feet of grate and 78 square feet of effective heating surface, 30 per cent. of which is fire and 70 per cent. flue surface. The average absorbing value of this surface is 2,000 B. T. U. per square foot.

$$78 \div 3 = 26 \text{ sq. ft. heating surface per sq. ft. grate.}$$

This amount of surface absorbs the heat emitted from the consumption of 5 lbs. of coal per square foot of grate per hour, and thus each square foot of grate carries, at different pressures, the number of square feet of radiation indicated in the fifth line from the bottom of the steam table. Placing, however, the consumption of coal at 4½ lbs. per hour per square foot of grate, and the steam pressure at 2 lbs., each square foot of grate carries 154 square feet of radiation, giving

$$154 \times 3 = 462 \text{ sq. ft. of direct radiation}$$

as the total capacity of the boiler. A water heater of identical construction and heating surface, burning the same amount of

coal at a temperature of 170 degrees Fahr. in the radiators, carries 288 square feet of radiation per square foot of grate, giving,

$$288 \times 3 = 864 \text{ sq. ft. of direct radiation}$$

as the total capacity of the heater.

Of course, by increasing the consumption of fuel, the capacity of these boilers can be increased, under the other conditions given, but only a little in excess of the amounts indicated by the intersecting columns, beginning with 2 lbs. and 170 degrees, at the top, and 5 lbs. of coal at the left.

The percentage of increase for the water rating is as follows: B. T. U. emitted per square foot radiation per hour, at 70 degrees Fahr., at 2 lbs. steam pressure = 293.

Ditto, at temperature of 170 degrees Fahr. in the water = 177.

Then $(293 - 177) \div 177 = 65\frac{1}{2}$ per cent.

Knowing that there is a wide diversity of opinion upon this subject, this article has been prepared, though hastily, with the hope that it will prove interesting and of some value to the heating profession; the object being to obtain the opinion and experience of authorities, and perhaps induce a more thorough consideration.

DISCUSSION.

Professor Carpenter: I have made a good many tests of direct radiators and pipes in almost all sorts of conditions and I do not think I ever got as high a value as 400 British thermal units under any circumstance. I think it is certainly too large. But for indirect radiators it is a very ordinary and common amount. There are many other interesting questions which I think might be asked regarding the tables, but I understand these latter tables are calculated from the first ones given.

Mr. Mackay: Yes.

Professor Carpenter: And hence it would all be answered by stating they were calculated. Mr. Mackay shows that the hot-water radiator must be 65½ per cent. greater than the steam radiator. I think a number of the members of this Society, also some of the other societies, have had under consideration lately

the question of what the difference between water and steam radiators should be and it has been decided, at least by one of our affiliated societies, practically the same thing that Mr. Mackay has given. It strikes me that that standard cannot be adopted with any great degree of accuracy, but still it may be a very good thing to adopt 65 per cent., or 60 per cent., or 70 per cent., or something like that. It ought to be adopted with a distinct understanding that it is only approximate and that it will vary, depending on the conditions, anywhere between 40 and 125 per cent., and there is no particular reason for saying 65 per cent. more than 60 or 70 per cent., except that we specify certain conditions and certain forms of radiators. Now so far as the temperature conditions are concerned, 65 or 60 per cent. perhaps is correct. The amount of heat which is given off per square foot of radiator depends a great deal upon the form of the radiator. A thin, low radiator will give off a great deal more per square foot of heating surface than a thick high one. Now we are commonly putting in our houses thick, high ones, and we put in for hot-water heating, as a rule, thicker radiators than we do for steam. Consequently we load down our hot-water system with an excess of cast iron. Now that excess of cast iron does not do much good, and if we are going to put in thicker radiators for hot-water heating than for steam we must expect that the hot-water radiators must be larger and have more cast iron than the steam, even for the same temperature, and possibly 65 per cent. is about right. I had calculated some years ago, by going over a lot of tests, that there was a difference of 60 per cent., but that was because the conditions which I assumed were doubtless a little different from those which are ordinarily taken. The Carbon Club, made up of manufacturers of boilers, has adopted 65 per cent. after looking into the matter very thoroughly, and I am not prepared to say that 65 per cent. is not the nearest possible difference that can be adopted, when we take into account the common practice of using a thicker radiator for hot water than for steam. I think, however, if any practice is going to be adopted and put on record, we might as well adopt one that would be easy to figure or handle in our calculations. If 65 per cent. is about right, and it doesn't make any very great difference whether it is 2 or 3 per cent. one way or the other, I think we might as well take 66⅔ per cent., which brings our

radiator sizes in the relation of 2 to 3, and makes a sum which is rather more easily calculated. I think, on the whole, that Mr. Mackay has presented a figure which is just about as near the truth as can be obtained.

Professor Kinealy: I would like to ask Mr. Mackay a question. These tables, as I understand it, are taken largely from Schumann's book, were they not?

Mr. Mackay: Well, they were checked up by that.

Professor Kinealy: That is what I mean. The values or coefficients upon which the tables are based are taken from Schumann's book.

Mr. Mackay: Yes.

Professor Kinealy: Of course you understand that progress has been made since Schumann's day. We made progress this morning when Professor Carpenter's paper was read, so it does not do to tie to anything that is old. I notice that the heating value of your coal is 10,000 heat units, the effective thermal value of one pound. Of course that means a high grade of coal and a pretty high efficiency of boiler service to get 10,000. If you come out near where I live we would give you a coal whose total heating power was 9,000.

Mr. Mackay: That is soft coal. There is some soft coal that averages higher than that, though, professor.

Professor Kinealy: So that, too, affects the question—the kind of coal—how much of the total heating power of the coal can you get after you burn it in your boiler? That is one of the problems that the American Society of Mechanical Engineers has been wrestling with for some time, and while its members have not had any fights they have had a good many discussions. They say that all roads lead to Rome. It is extremely difficult to make a comparison between the hot-water surface a boiler will carry and the steam surface at about two pounds without coming mighty close to finding that one is 65 per cent. greater than the other. What you can get away below that, or away above, depends entirely on the conditions under which you are working. The ordinary rule of thumb is all right—increase the steam surface that the boiler will carry by two-thirds of itself and you will get the hot-water surface pretty close. Now whether you multiply by 1.6 or 1.65 is a difference of 5 in 160. That is 3 per cent. We do not know the

laws of the transmission of heat close enough to enable us to calculate our coefficients within 3 per cent. In fact, I doubt very much if we know them within 7 or 8 per cent. At the most our coefficients are approximations. They are true for one certain set of conditions and it is doubtful if in any two rooms you get exactly the same conditions. It is one thing to make a test in a laboratory where you control all your conditions; it is another thing to put a radiator in a room where you may put furniture before it or where you may cover it over with goods, or where you may have an open window interfering with the circulation of the air in the room. So that I think that 65 per cent. is all right. But I do not like standards unless they are standards that can be changed continually. If we say that this is a standard, that this question is settled and closed, what becomes of our progress? Are we to mark this street as closed and say you cannot go in this direction any longer? A standard is all right if it is very elastic, and can be changed continually. Let it be changed to suit our knowledge.

Mr. Kent: I have been trying to see what additional information I could get on this paper from the discussion I have just listened to, and I have learned that the figures in the table have been checked against Schumann's figures, and also have heard from Professor Kinealy that we have learned a great deal since Schumann's time and that we learned something this morning. I would ask him if he will kindly point out what error there is in the second line of this table; that is British thermal units emitted per square foot of radiation per hour at 70 degrees Fahr. The whole table depends upon that second line. If Schumann's results are wrong and we have learned something since, what change should we make in those figures to bring them up to Professor Kinealy's latest information?

Professor Kinealy: Mr. Chairman, that is a large contract. As I had occasion the other day to say, I am often asked questions that I cannot answer. Then the only way to answer them is to say that I don't know. There is nothing here as to the kind of radiating surface. It depends upon the kind of surface.

Mr. Kent: Cast iron.

Professor Kinealy: Of course, but what does that mean? It tells us nothing of the shape. It tells us nothing of the proportions. It tells us nothing as to whether there is a circulation

of air over it or whether there is not. I suppose the figures are close enough. How much they are out I don't know. I cannot undertake to carry around all the latest information in my head. Moreover I do not know Schumann's book sufficiently well to be able to point out the errors in a table in a paper which I have just received a few minutes before. So that I cannot answer the question. It is possible that I don't know. But I am not prepared to answer it now.

Mr. Kent: I want to use this paper for a practical purpose. I want to know how to determine the amount of cast iron radiating surface for a particular case, and until I have later information on the subject I am going to use these particular figures here. What I want to get at is if these figures are wrong please give the right figures. If Professor Kinealy says he don't know, I will have to go back to Schumann's figures and accept the figures in the table.

Now I want to make a little addition to the table, which I have talked over with Mr. Mackay, and which he agrees to. If you will take the first line at the top of the table, opposite to 10 pounds coal per hour per square foot of grate, the figures immediately under the words " radiation per square foot of grate," and divide them by 10, you will have another figure which I will place right below the table and call it square feet of radiation per pound of coal. That virtually shortens the table. Divide the figures by 10 and you have the square feet of radiation per pound of coal and then put a foot note on the assumption that the coal is anthracite and that it has an effective heat value of 10,000 heat units per pound. If you have the coal such as is obtained out in Professor Kinealy's territory, you will have to change those figures. You will only need half the radiating surface per pound of coal in St. Louis that you do in New York, but to do the same amount of heating you will need the same amount of heating surface. The only difference is you would use a different amount of coal. What use is it to tell us: " Well, we don't know whether these figures are right or not, and we have learned a great deal since Schumann's time." How much have we learned since Schumann's time? I have not learned anything on this matter since Schumann's time. I hope Professor Kinealy will send a contribution correcting these figures. Then this paper will be improved.

Professor Carpenter: In regard to the accuracy of these figures I would say that I think if we had the conditions under which the tests are made which are recorded in Schumann's book (I think they are really Peclet's tables), I think we would find them very accurate. For I found these tables quoted, checked almost exactly by test of pipe radiation. These tables, however, I think give results which are altogether too high for the modern cast-iron radiator under average conditions. You can count on a variation in our modern radiation of very nearly 25 per cent. of the amount of heat given off dependent on the form of the radiator. These figures answer very well for the most efficient form of a radiator; one which perhaps is not much over 30 inches in height and is only one layer and is freely accessible to air on all sides, would be 30 or 40 per cent. higher than some of the poorest forms of radiator, and taking everything into consideration, I do not know why as a basis of calculation these tables are not as good as any.

Mr. Blackmore: This is a very interesting paper, and the tables as calculated seem to be all right if the premises are correct. Mr. Mackay does not explain here how this thermal value, 10,000 British thermal units, is obtained. This is an important matter. These tables are based on the assumption of an effective thermal value of 10,000 British thermal units. This is exceedingly high in house-heating practice—so high that I have never been able to reach it. I was ambitious enough about ten years ago to undertake a series of experiments, and after spending six weeks I was compelled to give them up because I saw it would take me fully a year to carry them out, and to obtain anything like accurate results that could be accepted by myself or any one else as deserving of credit. Hence I feel that we ought to know how these results were obtained, that we may form some idea as to the amount of error that occurred in the process. I have never shown the results of the experiments to which I have referred, because they were very unsatisfactory to myself, but in making these tests I did determine what percentage of the value of certain coal I could put into water, and I was pretty sure there was not a great loss by radiation, because I worked at temperatures below 200 degrees, and 66 per cent. was the highest I was able to obtain of the value of the fuel.

Mr. Kent: Do you know the chimney temperature?

Mr. Blackmore: No, I do not. Four and one-half pounds of coal per square foot of grate was the rate of combustion when I obtained the best result with the size of heater I used, and it had 4 square feet of grate. With the most careful preparation that I could make at the time, I could only get 66 per cent. of the value of the fuel, which rated it much lower than 10,000 British thermal units. I think the calorific value of the fuel which I used at that time was something less than 14,000; it was anthracite coal. I would like to know from Mr. Mackay whether this was an actual test or whether this table was partly made up from assumed conditions. Mr. Mackay in giving the loss of heat through walls and windows said that that amount was calculated. Now if the thermal value of the fuel was determined in somewhat the same way, this experiment loses a great deal of its usefulness. But if the thermal value was determined in some practical way that we can measure the possible efficiency of such a test it would be of great value to us. I would like to have a few words from Mr. Mackay on that point. Then there are two other points about which I am a little surprised. That is the relative efficiency of fire-box surface and flue surface. Mr. Mackay seems to get much better results from flue surface than I have ever heard of others getting. I have not made any experiment myself on that, but generally I think he rates the fire-box surface as lower than it is. I would like to ask how that was determined. You will see what I mean if you will refer to his table where he shows the relative efficiency of the absorbing power with a certain percentage of flue surface on page 163, and a certain percentage of fire surface, which he considers fire-box surface. I have always considered that fire-box surface had a higher efficiency than he places upon it, and I would like to know just how he determined its value.

The other point that surprised me was that the surfaces at the bottom of the flue showed no appreciable difference when they were covered by non-conducting material. I have always been taught that heat would pass from a hot to a cold body directly in proportion to the difference in temperature between the two. I can hardly believe that even the bottom of the flue in a furnace is anywhere near as cold as the water in the boiler. Consequently there should be an amount of heat passed from the bottom of the flue to the water, and covering such surface with

non-conducting material certainly would affect the result. Yet Mr. Mackay makes the statement that it made little or no difference. I would like to know how that was determined.

Professor Carpenter: In accordance with my experience, I think the assumption that you can get 10,000 heat units per pound of good anthracite coal is a reasonable one.

Mr. Kent: I agree entirely with Professor Carpenter as to that. I would like to ask Professor Carpenter if he has found in burning anthracite coal at very low rates of combustion, whether he could burn it as well at three and four pounds as at ten pounds, and not make carbonic oxide?

Professor Carpenter: The answer to that question would be, that it depends entirely on the form of your flues and your boiler. In some of the heating boilers where the flues are restricted we can burn as low as two pounds of coal per square foot of grate per hour and get good results.

Mr. Kent: I understand that the figures in the second column of the first table in the paper mean the number of cubic feet of air per hour that was raised from 0° to 70° Fahr. by 1 square foot of radiation maintained at the temperature given in the first column. Taking the weight of 1 cubic foot of air at 0° at 0.0863 pound and its specific heat at 0.24, it would take 0.0863 x 0.24 = 0.0207 British thermal units to raise 1 cubic foot one degree, or 1.45 British thermal units to raise 1 cubic foot 70°. If 222 cubic feet per hour were heated 70° by 1 square foot of radiator containing steam at 230°, say 6 pounds gauge pressure, as in Mr. Mackay's table, this would give 222 x 1.45 = 322 British thermal units per hour. Mr. Schumann's table gives 323.51 for the same conditions.

Mr. Mackay: Mr. Kent is right about the table and the figures given therein. They are the result of our observations, and compare fairly well with Mr. Schumann's.

LXXVII.

TOPICAL DISCUSSIONS.

TOPIC NO. I.

What is the best method of connecting open feed-water heaters and exhaust pipes?"

Mr. Henry C. Meyer, Jr.: Mr. President, I would like to say that I handed in that question for the purpose of exhibiting here a rather remarkable curiosity that I am able to present to the Society through the courtesy of Mr. Warren Webster. It is a small section of an eight-inch vertical exhaust pipe, connecting an open heater with the atmosphere. On the inside you will notice there is about an inch of scale. I think it is interesting, in view of the fact that it shows that a very large quantity of water must have been carried through that heater into the pipe and passed out to waste. As you know, in an open heater the feed water falls from the top and trickles down over trap, and in some methods of connecting the heater, the entire current of exhaust steam is passed through the heater, of course, at a somewhat high velocity. In this case the steam has undoubtedly picked up a considerable amount of the feed water, and as the feed water was heated to a sufficient temperature, certain salts were precipitated and collected upon the sides of the pipe in the manner shown. It seems to me to indicate that perhaps it is a better arrangement to connect the feed-water heater by a branch pipe from the exhaust main in such a way that only the steam that is contained in the heater enters it, provided proper means for removing the air from that heater can be had. I believe that Mr. Webster has always recommended this method. The pipe extended from the heater in a vertical direction, and the scale was found at varying thicknesses for a distance of eight feet above the heater.

Mr. Percival R. Moses: I have just had to take out a heater with that arrangement—an open feed-water heater—an auxiliary heater. We ran one end of the exhaust pipe from the engine directly into this heater. We found that the water would rise

up and get into the exhaust pipe. We got our engines loaded up with water. We had to take out the open feed water entirely. I cannot use them except in vacuum systems. The returns, coming back into this heater, overflow into the exhaust pipe. The vacuum produced by the steam condensing seems to raise the water. You could run it, of course, but it was so difficult to keep the water from going into the exhaust pipe that we had to watch it very carefully, and we were afraid of it, so we took it out.

Mr. Henry C. Meyer, Jr.: I cannot see how that could happen, unless the system was improperly designed. It may be that the overflow pipe was too small in the first place.

Mr. Paul: I would like to ask if we could have a drawing showing the design of the connections of the heater?

Mr. Moses: I can make a sketch that will show it. (Mr. Moses made a sketch on the blackboard.) With the closed heater, of course, there is no possibility of that.

Mr. Meyer: It was simply a case of where the heater may have been of too small volume. I would like to add another thing. The heater which I refer to was not of Mr. Webster's make. I believe it is a custom of that company to always install the heaters on a single connection—that is, on a branch from the main pipe.

Mr. Moses: I would like to say that we had to carry a high pressure on the return; ran it sometimes up to nine or ten pounds.

Mr. Paul: Mr. President, our experience in attaching a heater has been that you could get higher temperature of water by a one-pipe connection to the heater, proper connections being made to take care that the circulation would be full and complete in the heater. And where tests have been made, a one-pipe connection to the heater has brought up the temperature of the return water quite a number of degrees.

The President: Is there any further explanation of this problem which Mr. Meyer has presented to us?

Mr. Barwick: The only thing that we can suggest is, that there must have been some spray from the cold water, and the water must have held some lime in it that passed up through that pipe. That is the only thing I can think of.

Mr. Meyer: That is what occurred.

Mr. Barwick: I would like to ask Mr. Meyer one question:

Was that feed-water heater fitted with a back-pressure valve on the exhaust pipe?

Mr. Meyer: I am unable to say.

Mr. Barwick: That would govern the thing a good deal.

Mr. Meyer: How?

Mr. Barwick: Why, there would not be the loss in passing through that particular pipe.

Mr. Meyer: There might be sufficient velocity to cause the steam to pick up the water if the pressure of the exhaust exceeded the pressure for which the back-pressure valve was set.

Mr. Barwick: It would only be in proportion to the condensation of the steam. That is all it would take, unless it was absolutely passing through the feed-water heater and then through the exhaust to the roof.

Mr. Meyer: That is what it was doing.

Mr. Barwick: Then, of course, there was no back pressure.

Mr. Barron: I think that branch connection or by-connection, as Mr. Meyer suggests, is the only proper way to connect either closed or open heaters. The other connection is simply the old idea clinging to us, that we must have an outlet for the steam to get away—that same old-fashioned idea that blocked the one-pipe system of heating so long; and the same thing prevails in feed-water heaters. When they first came out, of course, they were crude, and the early engineers connected a pipe and supplied them with steam and the same size pipe to take it away. The same idea prevails still to some extent. Twenty-five years ago it was quite common to take a branch connection to the heater, and they got just as high a temperature as the men who put in the other connection.

Mr. Barwick: Mr. Barron, the people that make specifications are in business to make money, and the more the thing costs, the more money they make.

Mr. Barron: I think it is that these men who originated this way of doing work had not acquired any new ideas, and they wanted to make the best job they could, and they were not deterred by a little extra expense; that is all. I do not think Mr. Barwick's explanation is the proper one, or that those who make specifications are governed entirely by that idea. They want, of course, to make a reasonable profit, but it is their idea to make a good job, and that is what they considered was a

good job. This man who connected up this open heater that Mr. Meyer has reference to, probably did an expensive job and thought it was the right way to do it. He could have done it cheaper and better by merely making a branch connection to the heater.

Mr. Barwick: I think Mr. Barron is right in connecting up heaters with a single connection as long as we can drip it and get rid of the air. I find a good many that I have put up in that way have been very satisfactory, much more so than the other, and they cost a good deal less money. I cannot see any reason for putting a by-pass around a feed-water heater. I think it is a waste of money.

TOPIC NO. 2.

"What is the best and most practical method of heating and ventilation for hospital wards?"

Mr. D. M. Quay: I think it was three years ago that we were called upon to make plans and specifications for the heating and ventilation of a hospital, and especially the section of the hospital devoted to contagious diseases. That brought up the question of burning the vitiated air or treating it in some way to prevent it from carrying disease, and we found it a pretty deep question. We could not find many data and had to do a great deal of figuring and guess work, and put them together, and I have been anxious to hear that question discussed by our Society, to see if any of the members have had any experience in burning or treating this air.

Mr. William Kent: I once was in a hospital ward in my own house. It was in Pittsburg. I was lying very ill there and I was a crank on fresh air. I had, perhaps, the most perfect system of ventilation known—the open grate fire. Everybody had that in Pittsburg. I took it into my head, while I was lying in bed, that I had to have the windows opened wide once or twice a day. The temperature out of doors was somewhere near zero. I would get under the bedclothes for a minute or two while all the windows in the room and in the next room were opened wide and a cold blast of air swept through the room. I always felt exhilarated afterward. It seemed to me that there is something in that fresh cold air that is always good for the patient. Yesterday we heard a good deal about skunks and garbage barrels and

boiled sewage getting into the fresh-air ducts, and now I give you that little experience of my own. I confess myself a fresh-air crank, and in favor of opening the windows every time, if you don't strike the man in the back of the neck with a draught.

Mr. Stewart A. Jellett: The question as worded is pretty broad: "What is the best and most practical method of heating and ventilation for hospital wards?" The gentleman on my right suggests that the best method is to hire a competent engineer. But we want to go a good deal further than that. The first question really met with always is the limit of cost. Now in deciding on the best method of heating and ventilating a hospital, you have to take into consideration the size of the building, the cost of it, the amount of money that can be expended in heating and ventilation, if you design the heating and ventilating system. But you do not usually find ideal conditions existing; that is, sufficient money to do your best. You have to meet the conditions as they are. I have designed plants in a great many hospitals, one small one, three buildings, in a cottage system used for epileptics. It was furnished probably a year ago. Their funds were limited indeed. Buildings had to be built, property purchased, and all done within a certain given specified sum which could not be increased, and in order to start it at all it was necessary to take care of a certain number of patients, that is, the State agreed to give a certain amount of money, provided the people interested raised another amount. But the State insisted that a certain number of patients should be provided for. The conditions were fixed, the matter was very carefully calculated and a limited amount of money put in the whole plant. With epileptics it was out of the question to use gas or oil lamps. Therefore the electric lighting had to be put in. We use in that institution a gasoline engine to drive the dynamo which lighted the buildings by electric current. The same gasoline engine which drives the dynamo, during the day drives a deep well pump, with an auxiliary switch on the dynamo which increased its voltage to approximately 145 as against 110 and 112, and the surplus power over that required to work the pump charges a small storage-battery system for the use of night lights. The building was heated by direct-indirect radiation, low-pressure steam, gravity apparatus. The plant was put in at the lowest possible cost and it was designed so that one man could operate it. Pumping the

water or charging the storage batteries is done during the afternoon. The dynamo goes on until nine o'clock. Then the main switch is thrown and the storage battery is thrown on the night lights and nurses' lights, so that the whole plant is operated by one man. That is one way to design a hospital plant and it was the best way under those conditions. But if there was more money to devote to the purpose, the plant would not have been designed in that way.

In large city hospitals where there are a great many patients in a single ward, you are required to handle a very much larger volume of air, and the nature of the disease that is treated in that ward must be considered. We have taken buildings where as much as 4,500 to 5,000 cubic feet of air per hour was delivered. In these buildings were contagious diseases. I have taken others where I have got fairly good result and results that were entirely satisfactory on 1,800 feet. The cost problem was a different one. There was much less expense in original cost and much less expense in maintenance. As to the question that Mr. Quay refers to, about the air from wards occupied by contagious diseases, I have had two cases in this last year of contagious disease hospitals, one of which was an old building and a limited amount of money was appropriated by the State to remodel it. Out of that money they were compelled to build two sanitary towers, and the balance remaining over and above that was applicable to heating and ventilation. The matter was figured very carefully as to what could be done with that building and we put in a gravity apparatus. The building was in three wings. We warmed that building by direct radiation; but we put in each wing a tempering coil sufficient to give 2,000 feet of air per hour per patient, when the hospital was full to its maximum capacity. But a contagious disease hospital is like a bellows. One day it may have three or four patients in and three weeks from that time it may have three hundred. The escaping air passed through the original shafts of the building. Nothing else could be done, there was not sufficient money.

In the second hospital we connected all the returns with a series of down-draught flues with the main system of ducts in the basement, to which we attached an exhaust fan, and the air is driven to the battery of boilers. It passes through the fire and then out to the main stack, the intention being to destroy the

germs in that way. It is the cheapest way to get rid of them under the conditions, and as the boiler house was situated in such a way that we could do it with advantage we took that means of doing it.

In one accident hospital the physicians were very much opposed to fans or any mechanism in the building. The power system is some distance away. There we used indirect radiation, but we put in enormous flues and air ducts. The volume of air is brought in, in the most severe winter weather, at approximately 120 degrees. The temperature is maintained by putting in very large volumes. The vitiated air is entirely removed by aspirating coils in large towers. The building was built and designed particularly to handle large volumes of air at low velocities both coming in and passing out, and the results have been very satisfactory indeed, and those buildings have been in use now some five years. They get all the air they need at any time, and the tests made by the doctors show that the air is always in good condition. They have no difficulty in moving the volume they need by the method they are using. There is no machinery in the buildings.

Mr. Kent: I would like to ask Mr. Jellett whether the foul air is taken out at the floor level and how, and how the fresh air is introduced?

Mr. Jellett: In the building where we are burning the vitiated air we are taking it out on the side-walls close to the floor. The walls are narrow. There is a central hall in the building and the contagious disease cases are all isolated; that is, there is one patient in a room and that room is treated by itself. The walls are especially finished with a hard enamel finish and there are no washboards or anything like that about the room. It is done to prevent, as far as possible, the lodging of decayed matter or anything of the kind. The registers are set into the enamel finish. There are no valves in them, and no means of shutting them off. If the building is in use at all for contagious diseases the fan must run. If the building is shut off, then we cut the entire system off. The building is intended exclusively for contagious diseases and never used except for that.

Professor Kinealy: As I understand Mr. Jellett, although he has not said it here, I think he conveyed the meaning that I have, that is to say, that there is no best system, that each par-

ticular set of conditions requires a certain system which may be better than some other system. There is no condition that you can put your finger on and say this is the best for all conditions. But each set of conditions requires a special study and a special system in order to get the results you are seeking for, and that system is best which will give you the results you seek for at the minimum running expense, counting, in running expenses, interest on first cost, depreciation and repairs, cost of attendance, and cost of fuel. Is that what you mean, Mr. Jellett?

Mr. Jellett: Yes, sir.

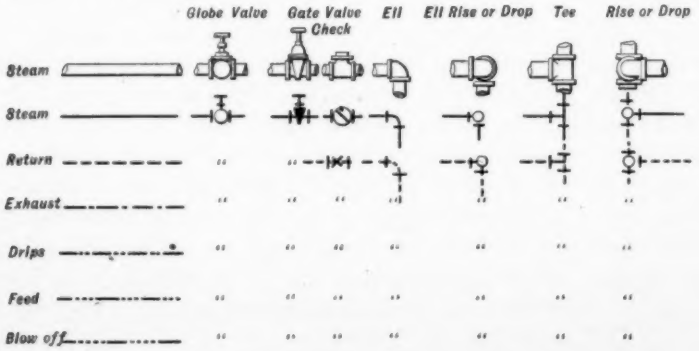
TOPIC NO. 3.

"Is there a recognized system of symbols for the marking of drawings, for the designation of pipes, ducts, etc.? If not, should not a sign language be adopted for the interpretation of drawings?"

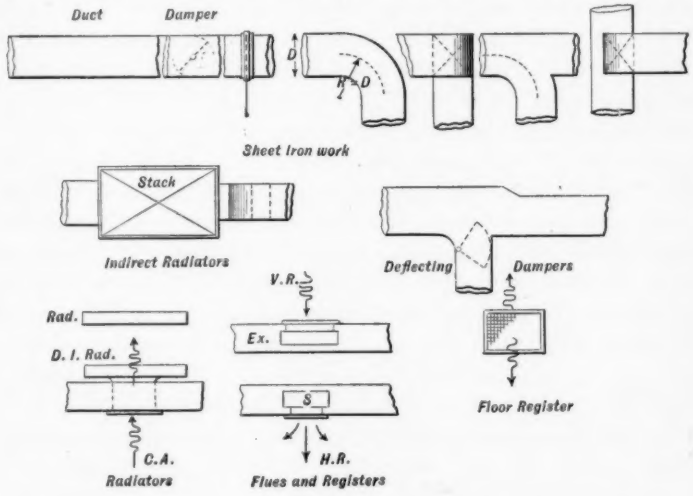
Mr. Barwick: In answer to the second part of the question I will say yes. To the first part I will say that I have used a method somewhat similar to our president's, following out with solid lines for the steam pipe, dash lines for the returns, dash and dot lines for the exhaust, dash and two dots for drips, dash and three dots for feed connections, dash and four dots for blow-off connections. For the power lines I have usually used a solid line, though in some cases I have used a double line, the same as with the steam-heating lines. In either case, where the fitting is required, it is shown. If an elbow rises from that fitting it is shown by a round ring or a dot; that is a filled-in dot. If it drops it is similar, with the exception that I mark it "drop." Every valve is shown and for check valves I have used a circle with a line drawn diagonally across it, or an x just made across the line. There are three sets of drawings the members can see. Each of them is an example of what we have done in our office for work that has been given to us, and it shows practically the method of laying out work that we have followed out. Our Philadelphia office follows a little different method. Where there is a rise of any of the mains they off-set it a little and show it in isometric shape. That method of forming an isometric drawing of it displaces the line from the actual position that it ought to be in. In those drawings I have shown practically the positions in which the pipes should run. Some of the work has been done in double line, showing every piece, valve, and fitting.

Some drawings that I made some years ago were made on scales running from 200 feet to the inch to half inch; of course very small drawings. They were drawn in solid dot and dash lines. On the other drawings, eighth scale and quarter scale, they were shown in double lines showing each fitting, each valve, each trap, practically everything as it ought to go. On one set of drawings which was made for the United States, where the present work was in the building, I laid it out with solid lines for the present work, and double lines for the new work. I think it would be better if other men in designing plants would follow the system as laid down in this way—I don't say follow the double line, because it is a very expensive system and you cannot afford to do it even on a five per cent. basis and make good drawings (that is for small drawings), and get everything on the drawing, so that it can be read very clearly. But with the ordinary lines, dot and dash, I think you can make a very good drawing and as accurate, and as easy to be read as any other method that I know of. All contractors as a rule cannot afford to spend the time to make drawings of that nature. The drawings that I show you there are drawings that we have received engineering commissions for, and they are all made on the above principle. There is a key placed on the bottom of the drawing which shows the character of each pipe line. The pipe is stated and what it is intended for. The fittings are shown. The T's are shown in three lines running out at an angle. Where a rise is taken from the same it is shown with a dot; elbows are shown in the same manner.

Mr. Barwick furnished the accompanying illustration of his system of symbols:



Mr. Quay: We scarcely find two architects that adopt the same style of plan, the same methods, and I question whether you will find two engineers that follow the same rules. As has just been said, you frequently see a set of plans, and say they are a certain engineer's plans. He adopts certain rules. Another engineer has other ideas. I question whether you could adopt any rule that all engineers would follow for that reason. They are peculiar people, you know; each one has his peculiar ideas, and he wants to have credit for anything he originates. They do not like to follow other people. Of course I think it is a good idea to have certain rules, so that the minute you look at a



plan you know what a certain mark means; but as for having a plan for all engineers to follow, I question the advisability of it.

Mr. Kent: There is a demand among young engineers to know what kind of symbols to use. I think if we can print Mr. Barwick's method in our Transactions and say this is recommended by one or two firms, there will be a great many engineers who will follow it. These old fogy engineers described by Mr. Quay will die out and the young ones will follow these printed rules.

Mr. Henry C. Meyer, Jr.: I think Mr. Barwick's method of indicating lines by alternating one, two, or three dots with a dash confusing, for if you notice a line upon a drawing you have

to count whether it is composed of three or four dots to determine what the line indicates. The accompanying sketch shows a convention that is more simple and I think more easily understood. There are usually very few high-pressure steam lines in a plant and they are indicated by a dash and two dots. The exhaust steam lines are also not many in number and they are indicated by a dash and a dot. The low-pressure steam lines are far more numerous and these are indicated by a straight line, which is much easier to draw than either of those mentioned. The return pipes are probably next in number, and these are indicated by short dashes. Fresh-air flues are indicated either by a rectangle with parallel lines or by a plain rectangle, the former being used if the walls of a building are not cross-sectioned, and the latter if they are so indicated. Foul-air flues are indicated by a solid black rectangle if the building walls are either cross-sectioned or not. If building walls are made solid black, of course this latter convention will not do. In that event the fresh-air flues can be a plain rectangle and the foul-air flues cross-sectioned. All of the conventions mentioned are rather easy to make and show up well upon blue prints. Of course, the best method of indicating different pipes and flues is by the use of different colors, but that, of course, is impossible in most work.

TOPIC NO. 4.

"When heating by direct radiation, should the radiators be placed close to an outside or an inside wall? And if placed by an outside wall, should they be placed between or before the windows?"

Professor Kinealy: I offered that topic, and in the discussion of the paper on hospitals the other day, I asked a question that I thought would bear somewhat upon this. I asked whether it would be better to have the vent at the bottom or near the top of the room, and the question was discussed, and I believe the conclusion was, that each room should be taken care of and judged by itself, and you should, as far as possible, make the air move according to the way in which it would naturally move in that room. Now, does that hold as well for heating as for ventilating? The air that passes over the radiator becomes hot and tends to rise to the top. The air that comes in contact with the window becomes cold and tends to fall to the floor. If you put

the radiator in front of the window, the hot air tends to rise and the cold air tends to fall. You impede or stop the circulation. If you put the radiator between the windows, the air in contact with the wall is not cooled so much, the upward draught is not so strong, and therefore the downward current will not impede the upward current quite so much. Now, the question is, which is the better position, and if neither be right, should the radiator be put next to the warm wall? In that case you have the air rising from the radiator, going up to the top of the room, falling as it comes in contact with the windows in the cold wall to the floor, and cold air sweeping over the floor to the radiator again. I would like to have an opinion from some of the gentlemen who install apparatus and have had some experience in the matter.

Mr. Payne: I believe it is sometimes the rule on board ship, that a junior officer expresses an opinion, and so it goes on up to the captain, and then he overrules all. So, perhaps, I might say a few words in regard to the question before us. I believe that the proper location for a radiator is between two windows, or beside a window if they should not be too close together in the same wall, because I think that the cold air dropping down from the window on top of the radiator is inclined to retard the circulation, whereas, if placed between the windows or beside one the natural tendency of the air is to pass along the floor towards the radiator and then on being heated rise to the upper part of the room. I had one experience in regard to placing radiators on an inside wall. I secured a contract in the country and did not make any plan, because I had a man who was a pretty fair steamfitter to do the work. I sent the materials to the house and the man had instructions to go at once. I did not see him before he started, and he erected the plant according to his own ideas. He wanted to get out of it as cheap as possible and so installed all the radiators on the inside wall. When the cold weather came along it was reported that the plant did not heat satisfactorily. I was satisfied there was enough radiation to do the work and I concluded it was because of a mistake in the location of the radiators. I had the job altered and the radiators put at the outside wall, and the house was comfortable.

When in Detroit I was speaking with a gentleman there with whom some here are well acquainted. I found that he favored the theory of placing radiators on the inside walls—at least, he

did then. I contended that it was wrong, and he said, "You come with me to a house, and I will show you." So we went to the house and went upstairs to one of the rooms. It was a sitting-room. "Now," he said, "there is the radiator; this room is comfortable, and we get a very good, positive circulation of air." A lady sitting in the centre of the room said, "Yes, I know that, because I feel the air passing along my feet." It was coming from the windows and outside walls, right to the radiator. I had a quiet laugh at him, and yet he was very positive. He said he could do far more work with the same amount of fuel, with less radiation, by placing the radiator on the inside walls than on the outside. I think the proper place for the radiators is where they are needed—that is, where it is cold, and the rest will take care of itself.

Mr. Kent: I had a similar experience, not with a radiator, but with an ordinary furnace in my house. The intelligent architect who designed the house thought he would run the heating pipes in the shortest possible course. So, to heat the library he ran a very short pipe from the top of the furnace to a point in the middle of the transverse wall of the library, and this natural circulation that we heard of from Professor Kinealy flowed from the window down along the floor and kept the people complaining of cold feet. I had the position of the register changed and put it right in the bay-window, and then had a conflict there between the cold air trying to go down and the hot air trying to go up. That made a situation that was exactly right, and we had no more trouble.

Mr. Wiltsie F. Wolfe: As a matter of information, leaving aside the matter of appearance, can we not get more units of heat from the same amount of steam if the radiators are placed on the ceiling than if placed anywhere else?

Mr. Mott: I agree with Professor Kinealy, that not only should the radiators be underneath the window, but also they should project above the window-sill, and by so doing form a pocket, by which the air falls down when it strikes this pocket and is turned over the head of a person sitting near the window. Otherwise, if they are put on the level of the window-sill, it will strike a person sitting near the window, in the head or chest. If it is carried up so as to form that pocket, it will throw it well above the head.

Mr. F. Herbert: I would like to ask a question for information on a somewhat analogous subject, and that is in regard to the placing of steam coils above or back of a fan. I have not any information on that point which is not directly under this head, but I would ask that that may be brought up.

The President: That would not come in under the discussion of this topic, but will be answered after we are through with the discussion of this topic. Is there any further discussion on this topic?

Mr. Barron: I think it would not do any harm to discuss the question the gentleman raises. I believe the opinion of the authorities in hot-blast heating is, that it is a mere matter of convenience whether you place the fan above or back of the heater. You make a more compact job where you draw the air through the heater and the fan, and also take up much less room. Where you put a fan to force the air through the heater, the apparatus takes much more room. I think that is the only consideration that governs any one in putting a plant in; at least, that is my experience.

With regard to radiation, I think a square foot of surface in front of a window or near a window is more effective than a square foot of surface in the rear of the room. But the steam-fitter, I think, is generally governed by the opinions of those he is doing the work for. If they ask his opinion, he tells them to put it on the exposed wall or near the window surface. The practice of steam-fitters generally is, I think, to put it on the exposed wall or near the windows or under windows. There are many practical objections to putting a radiator in the window or very close to it, but to get it as near the exposure as possible, I think, is the practice that nearly everybody follows, and what was laid down by Baldwin years ago.

TOPIC NO. 5.

"When testing radiators, what should be considered the maximum allowable error in any one test of a series?"

Professor Kinealy: I would like to hear from some of the members on this topic, which I introduced also. But it seems nobody will discuss it unless I say something about it. I would

like to know, if possible, what ought to be considered as a reasonable allowable error. What, with the instruments which we have and the methods of making tests, ought we suppose will be the error of any one test? It is impossible to make any kind of a test without an error being involved. Now, what ought to be considered as the probable error? For instance, the gas companies install meters. They know that there is a probable error in every meter that is installed. The electric companies install watt meters, and they know that there is a probable error in every meter installed. The meters in one house may run one or two per cent. too high; the meter in the next house may run one or two per cent. too low. Wherever observations are made, errors in the use of instruments and in making the observations are certainly involved. Suppose we made a number of tests of a radiator, and we describe as accurately as possible the conditions under which that radiator was tested; we get the average of all the tests; how many per cent. above this average should we expect the maximum result to be, and how many per cent. below this average should the minimum result be? That is what I would like to know. Can we be sure that when we make one single test of a radiator that there is a probable error, say, of not more than five per cent.? That is, the result may be five per cent. too low, or it may be five per cent. too high. If it is more or less than five per cent., what ought we to expect?

Mr. Kent: I would say it depends on the kind of test and on the nature of the instrument used, and the desirable accuracy in the work done. If Professor Kinealy was making a test himself in St. Louis, I would expect the errors of thermometer readings would be within one-half of one per cent. I would expect his weighings of water would be within one-half of one per cent. I would say anything beyond one-half of one per cent. in these two things would be beyond an allowable error. But if you are going to measure the heating of air by an anemometer or a Pitot tube, or any other way at present used, I would say there might possibly be an error of thirty or forty per cent. in a single observation. That ought not to be allowed; but it is because our methods of measuring air flowing through tubes are exceedingly crude and imperfect. If you take two radiators exactly alike and find they give results on two different tests that are ten or fifteen per cent. away from each other, neither one of

the tests is an error over one per cent.—they are nearly all correct. But the fact is, there are changes of conditions that may not have been observed, such as temperature of the room, or of surrounding objects, or the proximity of other radiators, or the condition of the surface, and so a broad distinction should be made between an instrumental error and a mistake in observation, and a variable condition which we have not yet been able to standardize.

Professor Carpenter: This question is, it seems to me, rather an interesting one, and I think I am rather inclined to agree with Mr. Kent, that the instrumental errors which would be likely to occur in the ordinary tests of radiators are very small, because we get our results from the measurement of quantities which can be very accurately measured. The errors which do come in testing radiators, are due to irregular conditions. One of the conditions which frequently changes and which ordinarily is not noticed, is the velocity of the air passing over the radiator. A change of a very few feet per second in the velocity of air may make a very great difference in the results. When I test radiators and want the results to check, that is, want to duplicate or triplicate the results, I put the radiator in an air-tight room, where there cannot be a current of air from outside over the radiator; it is the only way that I can repeat the same results two or three times running. Now, that condition I think has been overlooked so much in radiator tests that it has thrown suspicion upon the results from many very good tests. One man may test radiators and get very high capacity; another may test them and get very low results; the condition respecting the motion of the air not being observed in either case. So far as measurement of the quantities which are required for figuring out radiator tests, I think the error should not exceed with careful and skilled observers more than one-half of one per cent. But so far as duplicating the tests, the results are good if you come within ten per cent. This is due to a change of condition.

Mr. Kent: I would like to ask Professor Carpenter what he thinks of testing radiators by enclosing them in a tank with hollow walls, the spaces between the walls being filled with water, and the top being covered with non-conducting material. We can have a closed iron tank practically air-tight, with the outside

walls surrounded by water of a known temperature, and we can thus keep the conditions uniform.

Professor Carpenter: I hardly see the necessity of that construction, although it does present an opportunity for accurate testing. It perhaps might be a good precaution to get uniform results, but I think an air-tight room would give equally good conditions and not make conditions quite as artificial.

Mr. Kent: What were the walls of that room?

Professor Carpenter: We have built for our radiator tests a room perhaps 8 by 15 feet. The walls were constructed of thin studding and covered with very heavy building paper.

Professor Kinealy: In order to close this discussion, I want to say that I am glad to have heard from these gentlemen, and I think that it is just as much of an error not to see that the conditions under which we are making tests are the same for all the tests as it is not to see that our thermometers are correct, or that our scales are correct, and the gentlemen have brought out exactly the point that I wanted to bring out. I was called on only a short time ago to report on two tests of a building. In one, the windows were pulled down at the top a "little bit," in the other test they were not pulled down a "little bit." I think there is an error.

Mr. Kent: How many per cent.?

Professor Kinealy: That is exactly what I want to find out. A man is just as much to blame for not having his conditions the same as for using a thermometer which he knew was not correct. Why should we confine all our attention to the instruments that somebody else furnishes for us and do none of the work which we as testers should look after? Anybody can buy a good thermometer and read it. We should be careful that our conditions are as nearly as possible the same for all the tests of a series.

TOPIC NO. 6.

"In heating factories, is it wise to use only direct radiation without ventilation, or would it be better to use a forced circulation of warmed air?"

Mr. Barwick: That topic was given with the idea that we could get some expression from some of the members that had put in hot-blast heating apparatus and with coils. I wish to say

that I put in both styles of apparatus, and that as a rule I have found that the general health of occupants of factories, where the forced air circulation has been used, has been better than that where the coils have been used just simply for heating. I have talked with some superintendents of factories with reference to this matter, and in one building particularly, the superintendent said that the sickness among the girls had dropped from twenty-four per cent. to about five per cent. That gives a moral effect. The cost is practically very much the same. The cost in running expense is very much the same, provided you are utilizing your exhaust—that is, as far as the heating goes. There is a little cost required by extra power. I think that by using fans in factories we can get much better results from a moral point of view than by any other method of heating a factory building.

Mr. Barron: That question seems to me to be, in plain English, "Is ventilation as good as no ventilation? Is direct radiation with coils better than ventilation?" A very peculiar question to come before a society of ventilating engineers. That is the only way you can construe it. That is really what it means. It is an absurdity on its face, in my opinion.

TOPIC NO. 7.

"What is the most efficient and economical manner of taking care of drips from steam systems where the condensation is not returned to the boiler by gravity?"

Mr. Paul: The first thing I would want to know would be the basis under which the system is used, because that governs the whole question—whether you are going to use forty or fifty, or ten or twenty?

Mr. Connolly: It is high-pressure steam.

Mr. Paul: I do not deal in high-pressure steam very much, so I don't want to say much about it.

Mr. Barron: Mr. President: It may possibly be that some one wants that information. There is one general method used, that is, to take returns from an ordinary system with a pump governor and return to the boiler. I do not know any better method. It is the method that everybody uses. Until some

better method is evolved, I think it is as well for us to continue using it.

Mr. Kent: I understand the question is where the condensation is not returned. In that case, what is the matter with a gravity trap discharging into a cooling tank and from there into the sewer?

TOPIC NO. 8.

"Cannot a schedule be devised for the proper ventilation of toilet rooms in public buildings, doing away with deodorizing appliances?"

(No discussion.)

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